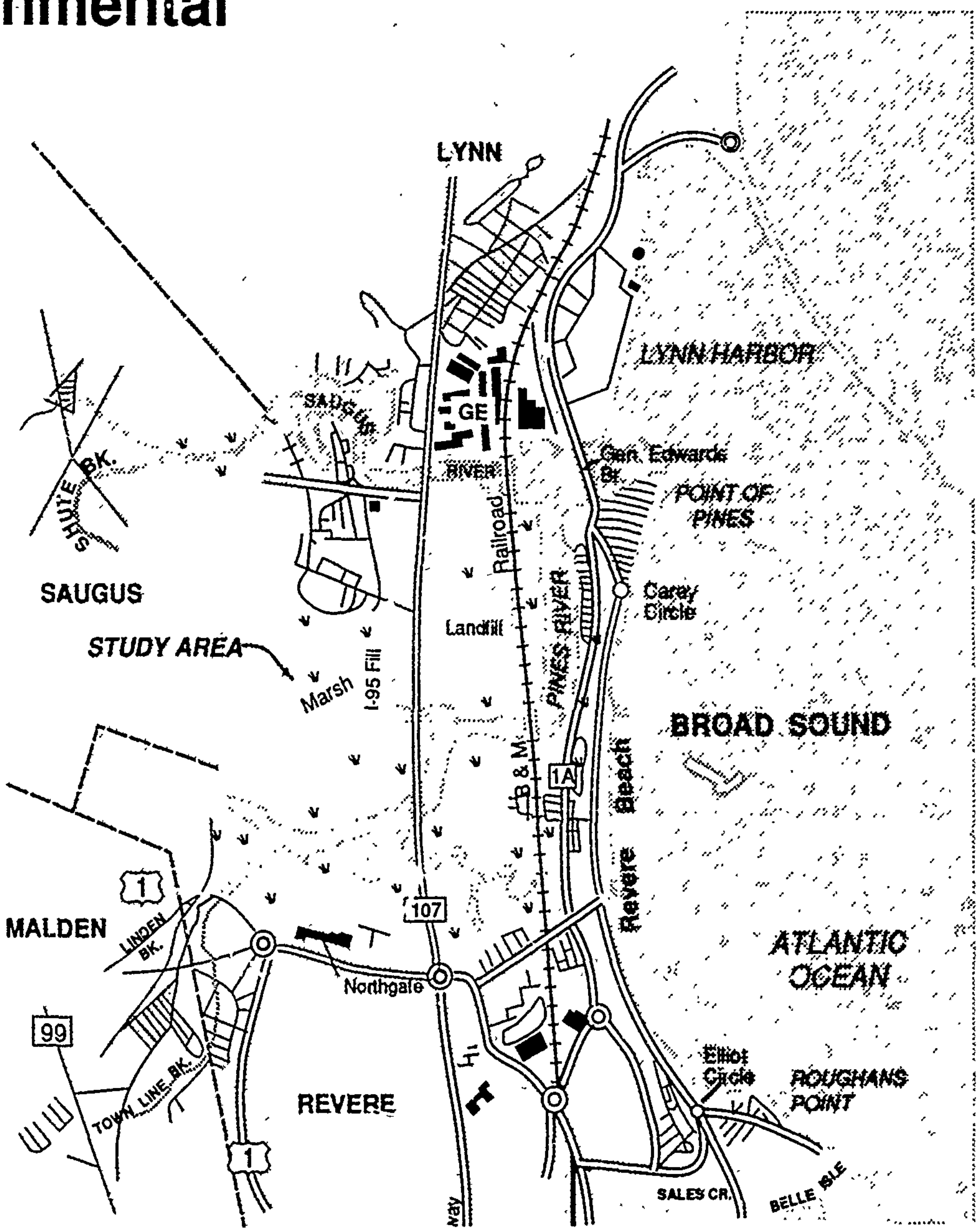
Feasibility Report - Draft Environmental Impact Statement/Report
Water Resources Investigation

Saugus River and Tributaries, Lynn, Malden, Revere and Saugus, Massachusetts

Flood Damage Reduction

Volume 8
Appendix
K - Environmental



US Army Corps of Engineers
New England Division

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED

1b. RESTRICTIVE MARKINGS:

2a. SECURITY CLASSIFICATION AUTHORITY:

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE:

3. DISTRIBUTION / AVAILABILITY OF REPORT: UNLIMITED DISTRIBUTION

4. PERFORMING ORGANIZATION REPORT NUMBER(S):

5. MONITORING ORGANIZATION REPORT NUMBER(S):

6a. NAME OF PERFORMING ORGANIZATION: U.S. Army Corps of Engineers-New England Div.

6b. OFFICE SYMBOL *(If applicable)***:** CENED-PL

6c. ADDRESS *(City, State, and ZIP Code)***:** 424 Trapelo Road, Waltham, Mass. 02254

7a. NAME OF MONITORING ORGANIZATION:

7b. ADDRESS *(City, State, and ZIP Code)***:**

8a. NAME OF FUNDING / SPONSORING ORGANIZATION:

8b. OFFICE SYMBOL *(If applicable)***:**

8c. ADDRESS *(City, State, and ZIP Code)***:**

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER:

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.

11. TITLE *(Include Security Classification)***:** Saugus River and Tributaries Flood Damage Reduction Study: Lynn, Malden, Revere, and Saugus, Massachusetts, Environmental Appendix K

12. PERSONAL AUTHOR(S): Robert Hunt - Project Manager

13a. TYPE OF REPORT: Final

13b. TIME COVERED: FROM Oct 85 TO Dec 89

14. DATE OF REPORT *(Year, Month, Day)***:** 06-89

15. PAGE COUNT: 98

16. SUPPLEMENTARY NOTATION: Title Variation: Flood Damage Reduction, Volume 8 Appendix K - Environmental

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
08	08	
13	02	

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*

Floods	Wetlands	Beaches
Flood Control	Water Quality	Inshore Areas
Flooding	Hydrology	Swamps

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

Includes basic data from investigations of environmental resources in the study area and presents Mitigation Incremental Analysis. Studies the following areas: geology, climate, hydrology, hydraulics, groundwater, water quality, sedimentology, wetlands, benthic habitats, beaches, artifical shorelines, plankton, fish, lobster, wildlife and rare and endangered species.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED

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22c. OFFICE SYMBOL: CENEDIM-SL

DD Form 1473, JUN 86 — *Previous editions are obsolete.* — SECURITY CLASSIFICATION OF THIS PAGE

(ADA-217 042).

Appendix K comprises two chapters. Chapter I provides detailed backup information on the significant resources described in Chapter 6 - 'Affected Environment' of the EIS/EIR, with the exception of socioeconomic resources-to be found in Appendix H - Socioeconomic. Chapter II is the Mitigation Incremental Analysis as required by Corps of Engineers regulations.

Further backup information is available in the various other appendices (see next page for complete list). Of particular interest would be Appendix B--Hydrology and Hydraulics, and Appendix C--Water Quality (both in ADA-217 040).

Additional materials pertinent to the EIS/EIR and this Appendix, such as grain size curves and further details on resources - down to the level of field sheets, may be inspected at the New England Division, Army Corps of Engineers - Impact Analysis Branch office. Keywords: Environmental impact statements; Massachusetts; Coastal engineering, Flood control, Wetlands, Flooding; Beaches; Inland areas; Swamps. (EDC)

Figure K1 is a Study Area Map for use with the information presented in this Appendix.

SAUGUS RIVER AND TRIBUTARIES FLOOD DAMAGE REDUCTION STUDY
Lynn, Malden, Revere and Saugus, Massachusetts/Summary of Study Reports:

Main Report and Environmental Impact Statement/Report (EIS/EIR): Summarizes the coastal flooding problems in the study area and alternative solutions; describes the selected plan and implementation responsibilities of the selected plan; and identifies environmental resources in the study area and potential impacts of alternative solutions, as required by the Federal (NEPA) and state (MEPA) environmental processes.

Plan Formulation (Appendix A): Provides detailed information on the coastal flooding problem and the alternatives investigated; includes: sensitivity analyses on floodgate selection (including location and size of gates and sea level rise); optimization of plans; comparison of alternative measures to reduce impacts; and public concerns.

Hydrology and Hydraulics (Appendix B): Includes descriptions of: the tidal hydrology and hydrology of interior runoff in the study area, and of wave runup and seawall overtopping, interior flood stage frequencies, tide levels, flushing, currents, and sea level rise effects without and with the selected project for various gated openings.

Water Quality (Appendix C): Includes descriptions of existing water quality conditions in the estuary and explores potential changes associated with the selected plan.

Design and Costs (Appendix D): Includes detailed descriptions, plans and profiles and design considerations of the selected plan; coastal analysis of the shorefront; detailed project costs; scope and costs of engineering and design; scope and costs of operation and maintenance; and design and construction schedules.

Geotechnical (Appendix E): Describes geotechnical and foundation conditions in the study area and the design of earth embankment structures in the selected plan.

Real Estate (Appendix F): Describes lands and damages, temporary and permanent easements and costs of the selected plan, including the five floodgate alignments studied.

Economics (Appendix G): Describes recurring and average annual damages and benefits in study area floodzones; economic analysis and optimization of alternative plans.

Socioeconomic (Appendix H): Describes the socioeconomic conditions in the study area and the affects of the selected plan on development in the floodplain and estuary.

Planning Correspondence (Appendix I): Includes all letters between community officials, agencies, organizations and the public and the Corps prior to agency and public review of the draft report.

Feasibility Study and EIS/EIR Comments and Responses (Appendix J): Includes all comments and Corps responses to letters received during agency and public review.

Environmental (Appendix K): Includes basic data from investigations of environmental resources in the study area and presents the Mitigation Incremental Analysis.

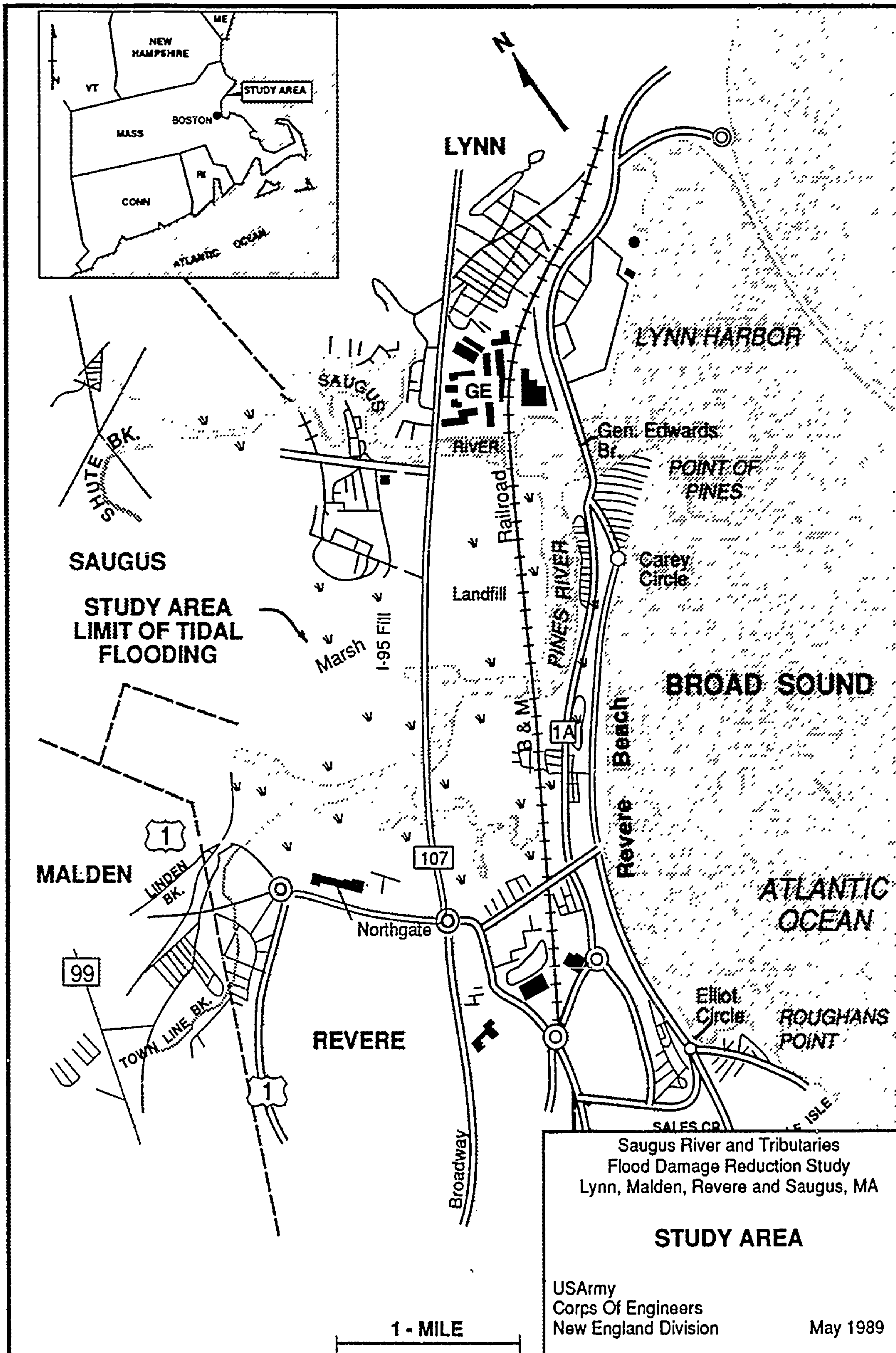
NEW HAMPSHIRE
ME
VT
STUDY AREA
BOSTON
MASS
RI
CONN
ATLANTIC OCEAN
N
LYNN
SAUGUS
GE
LYNN HARBOR
Gen. Edwards Br.
RIVER
POINT OF PINES
SHUTE BK.
SAUGUS
Railroad
PINES RIVER
Carey Circle
STUDY AREA LIMIT OF TIDAL FLOODING
Landfill
Marsh
I-95 Fill
BROAD SOUND
B & M
1A
Beach
Revere
1
MALDEN
LINDEN BK.
107
ATLANTIC OCEAN
Northgate
99
Elliot Circle
ROUGHANS POINT
TOWN LINE BK.
REVERE
1
SALES CR
Broadway
1 - MILE
Saugus River and Tributaries
Flood Damage Reduction Study
Lynn, Malden, Revere and Saugus, MA
STUDY AREA
USArmy
Corps Of Engineers
New England Division
May 1989

Figure K1

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Chapter I
Study Area Resources

A. Geology, Topography, Soils, and Seismicity

Historical

The proposed Study Area is situated in the topographic expression of a geologic feature called the Boston Basin. The Basin floor at the surface is a downdropped block of the older crystalline bed-rock which is exposed in the rim of the Basin. This rock was covered with silt and clay sediments which were consolidated into the present argillite bedrock basement. The last major geological event that greatly influenced the present landscape was the continental glaciation. The glacial ice first stripped the bedrock surface of weathered bedrock and soil and then redeposited these sediments as glacial till, a heterogeneous, unstratified mixture of clay through boulder-sized sediment sometimes in the form of a thin sheet and, more prominently, in the form of drumlins or ellipsoidal hills. At some time in the sequence of these events, either temporary glacial lakes were formed or sea level was higher, and clays of either lacustrine or marine origin were deposited. As the glaciers retreated, meltwater became the greatest active geological factor both in the deposition of sands and gravels and the erosion of channels in both the soft sediments and bedrock. In recent times, waves and currents have eroded and redistributed these glacial sediments to form beaches and lagoons. Finally, man has added fill materials over most of the Study Area.

Existing

Geology

The subsurface bedrock influences the topography of the Study Area. The Boston Basin is a structural as well as topographic depression filled by late Paleozoic rocks, chiefly sedimentary, which are younger than the crystalline rocks which rim the basin. The sudden change to a rocky terrain, which marks the northern part of the Basin and the Study Area, is the hanging wall of the Basin's boundary fault. In the Study Area this older rocky terrain starts just north of Washington, Walnut and Holyoke Streets in Lynn and just northwest of Lincoln Avenue in Saugus. The bedrock underlying the Study Area is the Cambridge Argillite, an indurated non-fissile siltstone and mudstone. There are no known surface exposures of the argillite in the Study Area since the top of this rock is in the range of 60 to 200 feet below the surface. The bedrock-soil interface is thought to be mostly unweathered, although some rock cores from the area show poor recovery which may indicate either a fractured or weathered surface. Elsewhere in the Boston Basin, the Cambridge Argillite is locally altered to clay (Kaye, 1967).

The sediments now overlying the bedrock are ice contact (till), glaciofluvial or marine in origin. Till, most prominently in the form of drumlins, is exposed on the south side of the Study Area. The till of the drumlins tends to be more stoney than the till of the general drift sheet which is buried in most of the Study Area. The till is overlain in places by clays of marine or lacustrine origin and/or outwash. A blue clay as well as a yellow clay have been noted in the area borings. The yellow clay may be a weathered variety of the blue clay. The clays are generally overlain by peat of salt marsh origin. The beach deposits are redistributed granular materials

from glacial outwash and till. Southward of the Study Area are several shoreline drumlins which, until earlier this century when sea walls were constructed, had been actively eroding from wave and current action. Rougha Point and Cherry Island Bar are the bouldery, cobbly erosional remains of a drumlin. The sand ar i gravel fraction of the drumlin tills was redeposited along the beach to .e north, while the silts and clays were carried offshore. Additional sands a i gravels were also added to the beach from the outwash deposits between ung's Hill and Crescent Beach. Point of Pines is wider than Revere Beach as it is comprised of a series of coalesced, recurved spits formed from sands transported northward in the longshore current.

Topography

The Study Area is located in the Boston Lowland Division (La Forge, 1932) of the Boston Basin. The Boston Lowland is bounded to the north by the Fells Upland, which for the most part, is delineated from the Lowland by an escarpment. The greater part of the Lowland along the coast is less than 50 feet above sea level. Locally higher areas (up to 175 feet above sea level in the Study Area) are mainly comprised of drumlins of which there are more than 100 in the Boston Basin, some of which are partially submerged and form many of the higher areas of the Boston Harbor islands. The more prominent nearby drumlins are in the southern part of the Study Area and include Youngs Hill, Fennos Hill, Beachmont, Orient Heights and Grover Cliff. The low areas are dominated by Revere Beach, a barrier beach which fronts a large salt marsh and the estuary of the Saugus and Pines Rivers. Revere Beach is bounded on the south by Roughans Point, a bouldery headland and on the north by Point of Pines, a sandy promontory which widens towards its end. The northern limit of the Study Area consists mainly of former marshland now filled and fronted by bulkheads, while the southern end is dominated by a sea wall fronted by a narrow beach which is mostly submerged at high tide.

Soils

The typical soil profile at the proposed Federal project site is 0-31 feet granular soils underlain by 0-26 feet organic soils, 16-109 feet silty clay, 0-41 feet sand and gravel (outwash or till) and argillite bedrock. The granular soils are man-made fills and natural deposits of mostly silty sand. Some of the man-made fills contain wood, concrete, bricks, metal, plastic, and other debris. The organic soils and silty clay are compressible materials which are consolidating due to the weight of the granular soils above them. The sand and gravel, and argillite bedrock are very dense materials which are undergoing little change at this time.

Seismicity

The proposed Federal Project lies in seismic zone 3 according to the seismic zone map of the United States (USACE, 1983b). The "major damage" rating has been assigned due to the concentration of earthquake centers in the Cape Ann area with Modified Mercalli intensities up to VIII.

B. Climate

The Saugus River Basin and its coastal vicinity, located at 42 degrees north latitude, have a cool, semihumid, and most variable climate, typical of New England. Fronting the ocean exposes the area to coastal storms that move northeasterly up the Atlantic seaboard often with accompanying intense rainfall, winds and flood-producing storm tides and waves. The mean annual temperature at Revere is 51° Fahrenheit with mean monthly temperatures varying from 72°F in July to 29°F in January and February. The mean annual precipitation in the Revere-Lynn area is 42 inches, based on over 100 years of continuous record at Boston. Precipitation is distributed quite uniformly throughout the year averaging about 3.5 inches per month. Average annual snowfall at Boston is 43 inches occurring primarily during December through March.

C. Hydrology and Hydraulics

Astronomical Tide Levels

General

Tides in the area are semidiurnal, with two high and two low waters occurring during each lunar day (approximately 24 hours 50 minutes). The resulting tide range is constantly varying in response to the relative positions of the earth, moon and sun, the moon having the primary tide-producing effect. At the National Ocean Survey (NOS) tide gage in Boston, Massachusetts (less than 10 miles from the Study Area), the mean range of tide and the mean spring range of tide are 9.5 and 11.0 feet, respectively. However, the maximum and minimum predicted astronomic tide ranges at Boston have been estimated at about 14.6 and 5.1 feet. A summary of the tidal datum planes for the Boston Gage is presented in Table K1.

At the Study Area

Due to the complexity of water movement within the Saugus and Pines Rivers Estuary and the lack of data there, tidal stage measurements have been made intermittently over the past three years to better define tidal motion within the Study Area (see Figure K2 for location of gages). In general, tide levels at the mouth of the Saugus River are found nearly identical to those at Boston. Tide levels in the estuary show some variance in height and timing from those at the mouth of the Saugus River. It was determined from measurements taken within the estuary, that for normal nonstorm tide conditions, the smaller the tide range, the less change there is in tide heights and timing as one proceeds upstream from the river's mouth. Mean tide range produces nearly the same elevations and timing inland as at the coast. For spring tides, the high tide tends to be lower and later inland and the low tide tends to be higher and later inland, than at the mouth of the Saugus River. Normal spring high tides at the Lincoln Avenue Bridge in the Upper Saugus River portion of the estuary and at the Seaplane Basin in the upper Pines River portion of the estuary appear to be about 0.1 and one-half foot lower, respectively, than at the mouth of the Saugus River and the timing

Table K1

BOSTON TIDAL DATUM PLANES
NATIONAL OCEAN SURVEY TIDE GAGE
(BASED UPON 1960-78 NOS TIDAL EPOCH)

	Tide Level (Ft. NGVD)
Maximum Predicted Astronomical High Water	7.5
Mean Spring High Water	5.8
Mean High Water (MHW)	5.0
Minimum Predicted Astronomical High Water	2.7
Mean Tide Level (MTL)	0.3
National Geodetic Vertical Datum (NGVD)	0.0
Maximum Predicted Astronomical Low Water	-2.4
Mean Low Water (MLW)	-4.5
Mean Spring Low Water (MLWS)	-5.2
Minimum Predicted Astronomical Low Water	-7.1

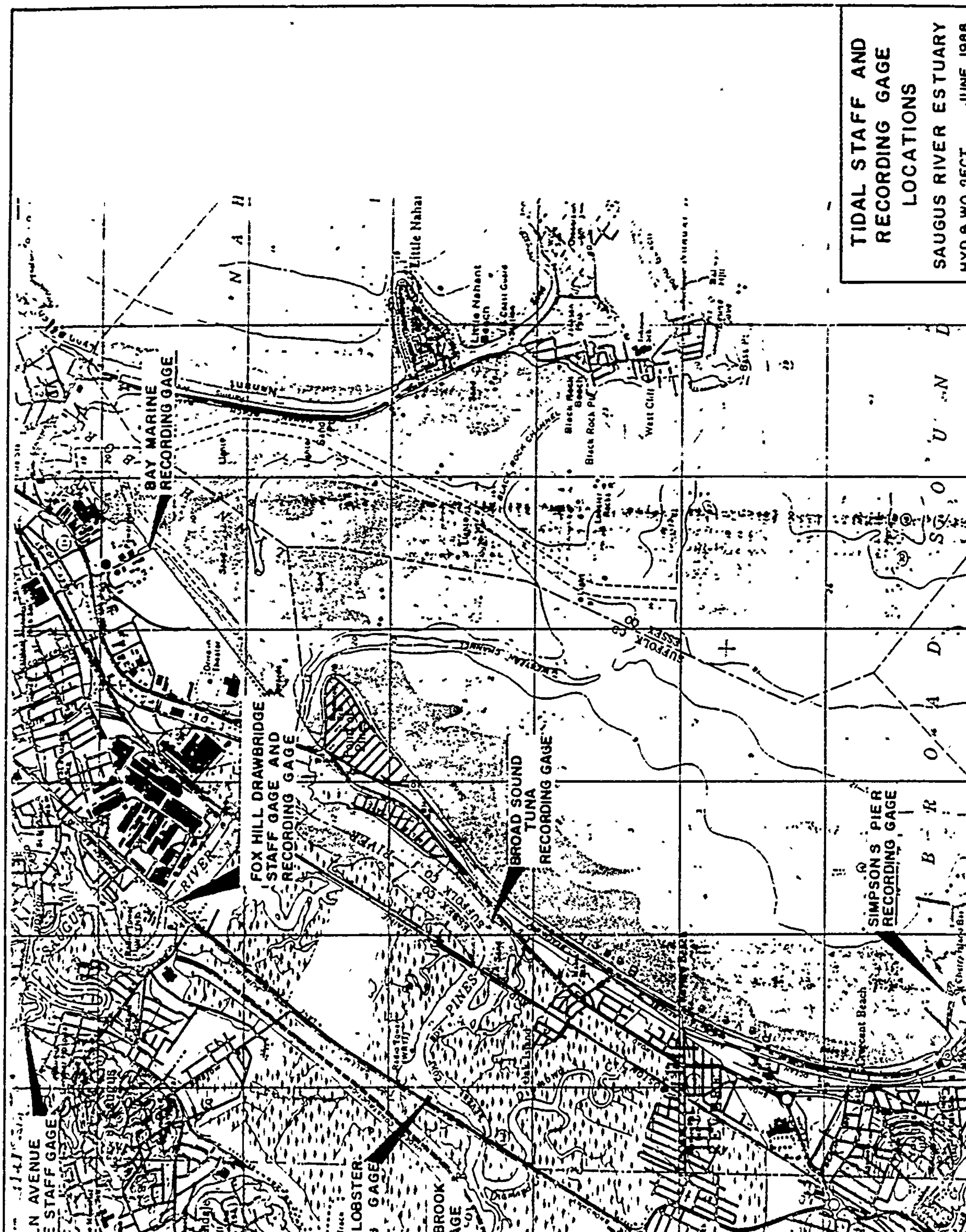

TIDAL STAFF AND
RECORDING GAGE
LOCATIONS
SAUGUS RIVER ESTUARY
HYD.& WQ.SECT. JUNE, 1988
LINCOLN AVENUE
BRIDGE STAFF GAGE
ATLANTIC LOBSTER
RECORDING GAGE
TOWN LINE BROOK
STAFF GAGE
FOX HILL DRAWBRIDGE
STAFF GAGE AND
RECORDING GAGE
BAY MARINE
RECORDING GAGE
BROAD SOUND
TUNA
RECORDING GAGE
SIMPSONS PIER
RECORDING GAGE
RIVER
PINES
Little Nahant
West Cliff
Black Rock Pt
Crescent Beach
SUFFOLK CO
ESSEX CO

Figure K2

appears to be about 5 minutes and 50 minutes later than at the mouth, respectively. On the upper Saugus River portion of the estuary the change seems to be due mostly to frictional impacts of the channel. For the upper Pines River portion of the estuary, however, the reduction in elevation is related mostly to the restrictive channel opening at the abandoned I-95 highway embankment and the relatively large storage available in the marsh. Larger differences occur at low water than at high water. Further information is provided in the Hydrology and Hydraulics Appendix.

Storm Tides

General

The combined effect of astronomical tide and storm surge produced by wind, wave and atmospheric pressure contributions is reflected in actual tide gage measurements. Since the astronomic tide range at the project is so variable, many severe coastal storms occur during periods of relatively low astronomic tides. Thus, even though a storm may produce exceptionally high onshore winds, waves and a tidal surge, the resulting tide level may be less than that occurring during a time of high astronomic tide and no meteorological influence. Figure K3 presents a tide stage-frequency relationship for the Boston NOS gage which was developed using historic annual maximum stillwater levels. Table K2 lists maximum annual storm surges determined by the National Weather Service in their "Tide Climatology For Boston, MA" (November, 1982) and associated observed tide levels at Boston. The recurrence intervals of the maximum observed tide levels recorded on days of maximum annual storm surge were generally less than one year, with only a few storms producing significant tidal flood levels. Some of the most severe onshore winds, waves, and storm surges are shown to have produced minor tidal flooding, owing to their coincidence with low astronomic tides. A good example of this is the November 30, 1945 event which produced the maximum storm surge of record at Boston of 4.9 feet; extremely high onshore winds occurred during low astronomic tide and resulted in only a minor tidal flood level (7.6 feet NGVD).

Conversely, rather significant tidal flood levels can result from the coincidence of relatively high astronomic tides and only minor meteorological events. Astronomic high tide level in Boston alone can reach 7.5 feet NGVD (see Table K1). With such a condition, a coincident storm surge of only 2 to 3 feet can produce major tidal flood levels. The February 7, 1978 storm tide at Boston reached 10.3 feet NGVD, the greatest of record, but was produced by a combination astronomic tide of 6.9 feet NGVD and surge of 3.4 feet, the latter being of only moderate magnitude (see Table K2 which shows that a surge of 3.4 feet is not extreme). Finally, Table K3 shows the maximum observed historical tide levels in Boston, and the same tides adjusted for sea level rise to update the data to present day levels. It can be seen that the Study Area obtains its damaging tide levels during the late fall, winter and early spring months, from extratropical "northeasters". Tropical cyclones have historically not produced significant tide levels at this east-facing coastal area.

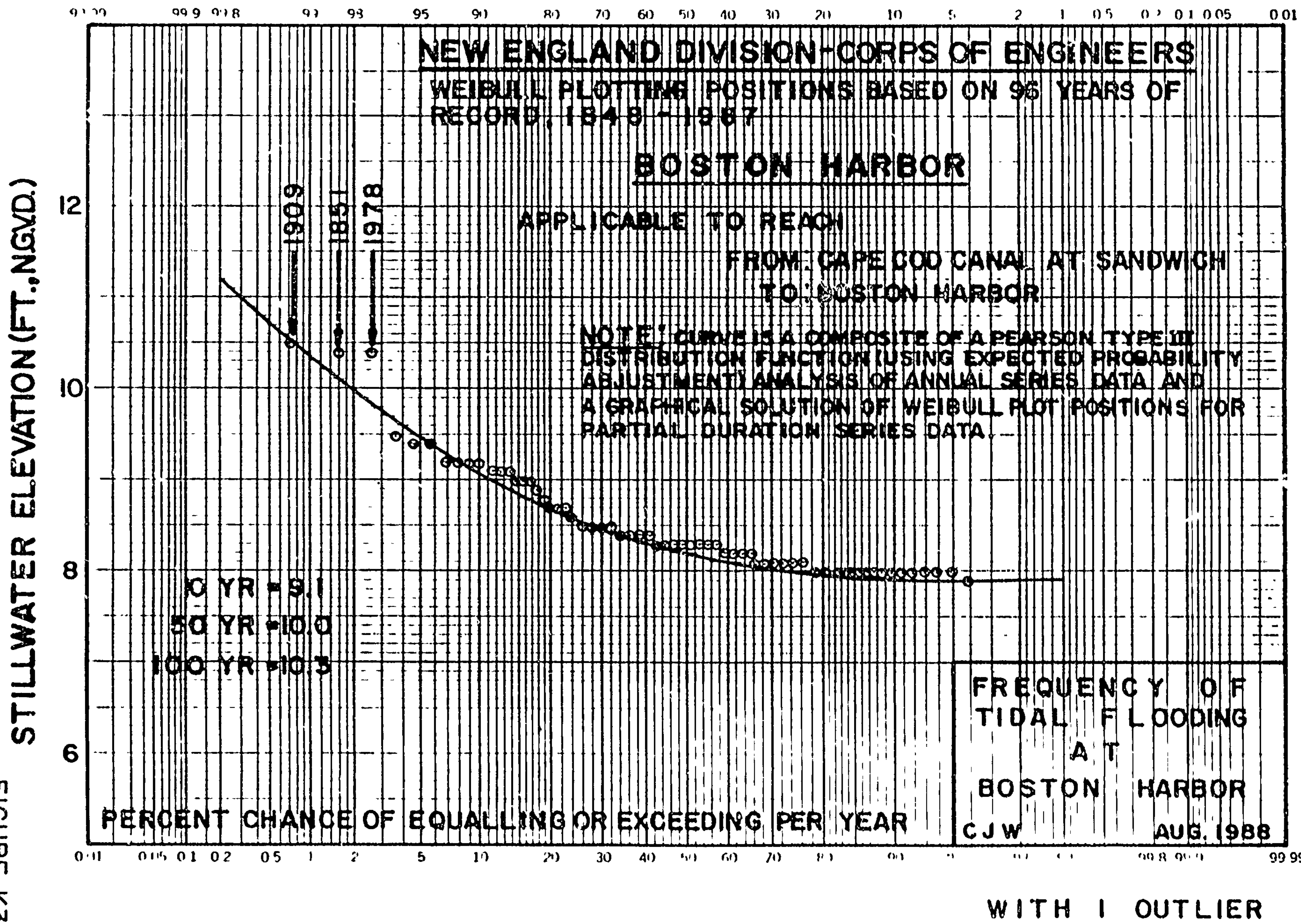

NEW ENGLAND DIVISION-CORPS OF ENGINEERS
WEIBULL PLOTTING POSITIONS BASED ON 96 YEARS OF RECORD, 1848-1987
BOSTON HARBOR
APPLICABLE TO REACH
FROM: CAPE COD CANAL AT SANDWICH
TO: BOSTON HARBOR
NOTE: CURVE IS A COMPOSITE OF A PEARSON TYPE III DISTRIBUTION FUNCTION (USING EXPECTED PROBABILITY ADJUSTMENT) ANALYSIS OF ANNUAL SERIES DATA AND A GRAPHICAL SOLUTION OF WEIBULL PLOT POSITIONS FOR PARTIAL DURATION SERIES DATA.
1909
1851
1978
10 YR = 9.1
50 YR = 10.0
100 YR = 10.3
STILLWATER ELEVATION (FT., NGVD.)
12
10
8
6
PERCENT CHANCE OF EQUALLING OR EXCEEDING PER YEAR
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
99.99
FREQUENCY OF TIDAL FLOODING AT BOSTON HARBOR
CJW
AUG. 1988
WITH 1 OUTLIER

FIGURE K3

TABLE K2

ANNUAL MAXIMUM STORM SURGE
BOSTON, MASSACHUSETTS
(1922-1979)

Date	Annual Maximum Storm Surge (feet)	Maximum Observed Tide Level for the Day (feet, NGVD)	Recurrence* Interval (years)
30 Nov 1945	4.9	7.6	LT 1
13 Apr 1961	4.7	8.0	1
6 Feb 1978	4.6	10.0	50
14 Feb 1940	4.2	5.0	LT 1
17 Nov 1935	4.1	6.5	LT 1
19 Feb 1972	4.0	9.1	10
3 Mar 1947	3.8	7.2	LT 1
4 Mar 1960	3.8	8.1	2
30 Jan 1966	3.8	5.5	LT 1
12 Nov 1968	3.7	7.7	LT 1
25 Jan 1979	3.7	9.2	13
22 Mar 1977	3.6	5.3	LT 1
25 Nov 1950	3.6	6.4	LT 1
31 Aug 1954	3.5	8.2	2
16 Feb 1958	3.5	7.9	1
15 Nov 1962	3.5	7.9	1
16 Mar 1956	3.4	5.6	LT 1
27 Dec 1969	3.3	6.7	LT 1
11 Mar 1924	3.2	6.2	LT 1
31 Jan 1939	3.2	6.9	LT 1
18 Feb 1952	3.2	7.9	1
7 Mar 1923	3.1	6.9	LT 1
20 Feb 1927	3.1	6.9	LT 1
19 Jan 1936	3.1	5.9	LT 1
7 Nov 1953	3.0	7.4	LT 1
14 Aug 1971	3.0	5.4	LT 1
29 Jan 1973	3.0	6.1	LT 1
12 Mar 1959	2.9	6.5	LT 1
16 Apr 1929	2.8	6.6	LT 1
8 Mar 1931	2.8	6.5	LT 1

*Recurrence interval of observed tide elevations. Obtained from tide stage-frequency relationship, Figure K3.

NOTE: LT = Less Than.

TABLE K3

MAXIMUM STILLWATER TIDE HEIGHTS
BOSTON, MASSACHUSETTS

Date	Observed Elevation (feet, NGVD)	Adjusted Elevation* (feet, NGVD)	Recurrence*** Interval (years)
7 Feb 1978	10.3	10.4	91
16 Apr 1851	10.1	10.4	63
26 Dec 1909	9.9	10.5	42
2 Jan 1987	9.4	9.4	17
25 Jan 1979	9.3	9.4	14
29 Dec 1959	9.3	9.5	14
27 Dec 1839	9.2**	--	13
15 Dec 1839	9.2**	--	13
19 Feb 1972	9.1	9.2	11
24 Feb 1723	9.1**	--	11
26 Mar 1830	9.0**	--	9
26 May 1967	8.9	9.0	7
21 Apr 1940	8.9	9.2	7
29 Dec 1853	8.9	9.2	7
4 Dec 1786	8.9**	--	7
20 Jan 1961	8.8	9.0	6
30 Nov 1944	8.8	9.1	6
4 Mar 1931	8.8	9.2	6
3 Dec 1854	8.8	9.1	6
3 Nov 1861	8.7	9.1	5
9 Jan 1978	8.6	8.7	4
16 Mar 1976	8.6	8.7	4
17 Mar 1956	8.6	8.8	4
7 Apr 1958	8.5	8.7	4
15 Nov 1871	8.5	9.0	4
23 Nov 1858	8.5	8.9	4
26 Feb 1979	8.4	8.5	3
2 Dec 1974	8.4	8.5	3
7 Mar 1962	8.4	8.6	3
4 Apr 1973	8.3	8.4	2
22 Dec 1972	8.3	8.4	2
28 Jan 1933	8.3	8.7	2

*Observed values after adjustment for changing mean sea level; adjustment made to 1987 mean sea level.

**Approximate value based upon historical account. Record not sufficient to document change of sea level for this time.

***Recurrence interval of observed tide elevations. Obtained from tide stage-frequency relationship, Figure K3.

NOTE: Events occurring within about 30 days of a greater tide producing event are excluded from this list. Events recorded during years for which only partial records are available were also excluded.

At the Study Area

Studies by the Coastal Engineering Research Center (CERC) for the adjacent Roughans Point Project have indicated that storm tide frequency in the Saugus and Pines Rivers system is nearly identical to that at the Boston NOS gage. CERC simulated surges for 150 randomly selected coastal storms using the WIFM model and determined their frequency. Results were presented in Technical Report CERC-86-8. The interior flood levels developed were at least equal to the stage-frequency curve at Boston (Figure K3) and in some cases a few tenths of a foot higher because of the effect of the wind within the estuary. Therefore, for this study the tidal stage-frequency relationship for Boston was adopted generally for use within the estuary. Based on Figure K3, the peak storm tide still-water elevations at the mouth of the Saugus River for the 1 percent (100-year), 2 percent (50-year) and 10 percent (10-year) chance flood events are 10.3, 10.0 and 9.1 feet NGVD, respectively. Developed flood-stage frequencies for individual areas around the estuary and on the coast are presented in the Hydrology and Hydraulics Appendix. In addition, Corps criteria calls for analysis of a standard project storm for the Study Area as discussed in EM 1110-2-1411. The standard project storm for this study, which is called the Standard Project Northeaster (SPN), is the "most severe combination of meteorologic and tidal conditions that are considered reasonably characteristic of the geographical region involved, excluding extremely rare combinations." The SPN stillwater level for this study has been determined to be 12 feet NGVD. For details as to how this was calculated, see the Hydrology and Hydraulics Appendix.

Streamflow

There are no streamflow gaging stations on the Saugus/Pines River System; however, based on gaged streams in the region, average annual runoff should be about 23 inches or about 50 percent of average annual precipitation. Twenty-three inches of runoff converts to an average annual flow rate, per square mile of watershed, of about 1.7 cfs. Thus, the Saugus/Pines River System with a total watershed area of 47 square miles, would have an estimated average annual natural runoff of about 80 cfs. However, the average annual natural flow is reduced by an estimated 10 to 12 cfs due to Wakefield and Lynn water supply diversions. This water is directed out of the basin, thereby reducing natural streamflow. Estimated average flows range from a high of 195 cfs in March to a low of about 12 cfs in August. Existing condition peak discharges for 1 percent (100-year) and 10 percent (10-year) flood frequencies are estimated to be 1,600 cfs and 700 cfs, respectively, for the upper watershed (25.7 square miles). Flow from the lower watershed (21 square miles) is made up of discharge from several short tributaries direct to tide water, and flap gated urban drains, plus rainfall directly on the extensive (500 to 1,000 acres) tidal basin water surface. Estimated peak 1 percent and 10 percent discharges for the lower watershed are 2,300 and 1,200 cfs, respectively. Further discussion on streamflow is presented in the Hydrology and Hydraulics Appendix.

Tidal Flushing Within the Estuary and Tidal vs. Freshwater Influence

As a result of the sluggish flow from the large upstream wetlands and ponding areas, freshwater inflow into the tidally influenced portion of the Saugus and Pines Rivers is a small component of the total estuarine flow.

Storage capacity in the Saugus/Pines River Estuary between normal low tide (EL-4.5 feet NGVD) and normal high tide (EL +5.0 feet NGVD) is 4,600 ac-ft. Therefore, with a normal tide cycle of about 12 hours there is an average rate of saltwater interchange of 9,400 cfs. At the peak midtide rate of change of about 2.4 feet per hour, the interchange rate is about 15,000 cfs. Under a spring tide range of 11 feet, total storage capacity is about 5,500 ac-ft for an average interchange rate of 11,000 cfs, and a peak midtide interchange rate of about 17,000 cfs.

Placing the freshwater inflow and tidal hydraulics of the estuary in perspective, the average rate of saltwater interchange to the estuary is approximately 100 times the average freshwater inflow from the watershed (9,400 cfs vs 80 cfs). Even under the rare condition of a one percent chance Saugus/Pines River flow coincident with a one percent chance local runoff, the peak freshwater inflow to the estuary would be only about 43 percent (4,000 vs 9,400 cfs) of the average rate of saltwater tidal interchange. The hydrology of the Saugus/Pines Rivers Estuary and its resulting environment, including flooding, is therefore, much more a function of the hydraulics of tidewater interchange than of watershed runoff.

Flooding - Tidal vs. Freshwater

Damaging flooding throughout the Saugus/Pines Rivers Estuary is caused principally by high storm tides. The stated purpose of this Study is to propose solutions to reduce damages due to tidal flooding. Neverthe-less, tidal flooding around the estuary could be affected by high freshwater flow coincident with high storm tides. The greatest known freshwater flow on the Saugus River occurred in October 1962 when rainfall amounts from 10 to 14 inches were experienced. This rainfall was the combined result of a "North-easter" coastal storm on October 5-6 and the fringe of tropical storm "Daisy" on October 6-7. It is noted however that ocean tides were not abnormally high during this major rainfall event (estimated at less than 7 feet NGVD). Since there are no streamflow gaging stations on the Saugus River the long term history of magnitude and timing of flood events is not available. Therefore, difficulties arise when attempting to assign precise coincident frequencies to high streamflow and storm tide levels. An analysis of the Old Swamp River gage near South Weymouth, Mass. for the period 1967-1978, at the time of storm tide (tide elevation 8.0 feet or over) reveals that while flows are several times higher than average conditions (see Figure K4), no significant coincident peak discharges had occurred during the time period examined. However a major flood event could occur coincident with storm tides and has been considered in determining storage requirements for the Saugus River and Tributaries Study Options.

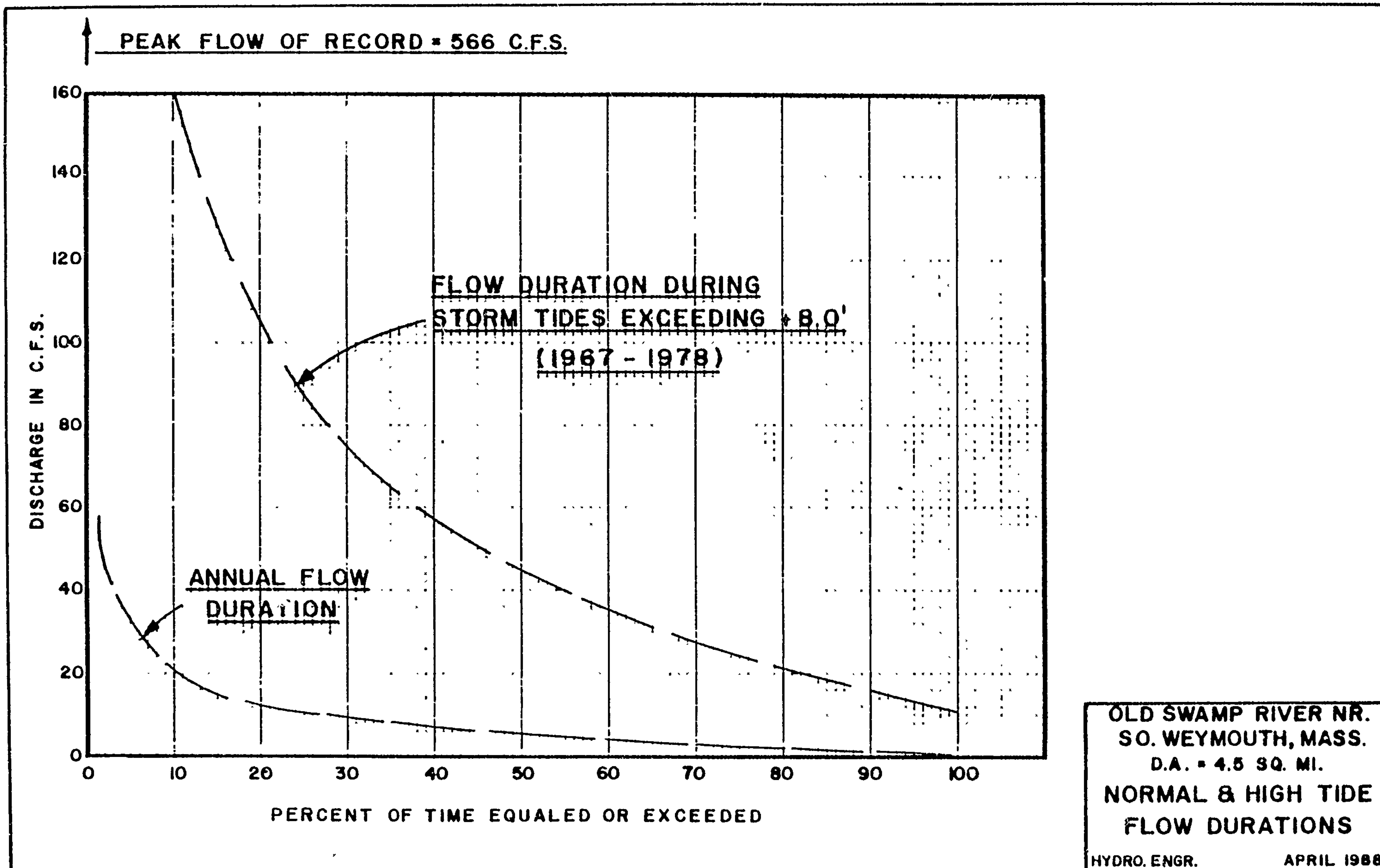

PEAK FLOW OF RECORD = 566 C.F.S.
DISCHARGE IN C.F.S.
160
140
120
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
90
100
PERCENT OF TIME EQUALED OR EXCEEDED
FLOW DURATION DURING
STORM TIDES EXCEEDING +8.0'
(1967 - 1978)
ANNUAL FLOW
DURATION
OLD SWAMP RIVER NR.
SO. WEYMOUTH, MASS.
D.A. = 4.5 SQ. MI.
NORMAL & HIGH TIDE
FLOW DURATIONS
HYDRO. ENGR.
APRIL 1988

Figure K4

D. Groundwater

According to data published by the U.S. Geological Survey (1980), there are no municipal or industrial wells within one-half mile of the Saugus/Pines Rivers Estuary. Water supply to the town of Saugus, the city of Revere and the emergency supply for the city of Lynn is from the Mass. Water Resources Authority's water supply system. Normal supply for the city of Lynn is from treated surface water from the upper Saugus and Ipswich Rivers.

E. Water Quality

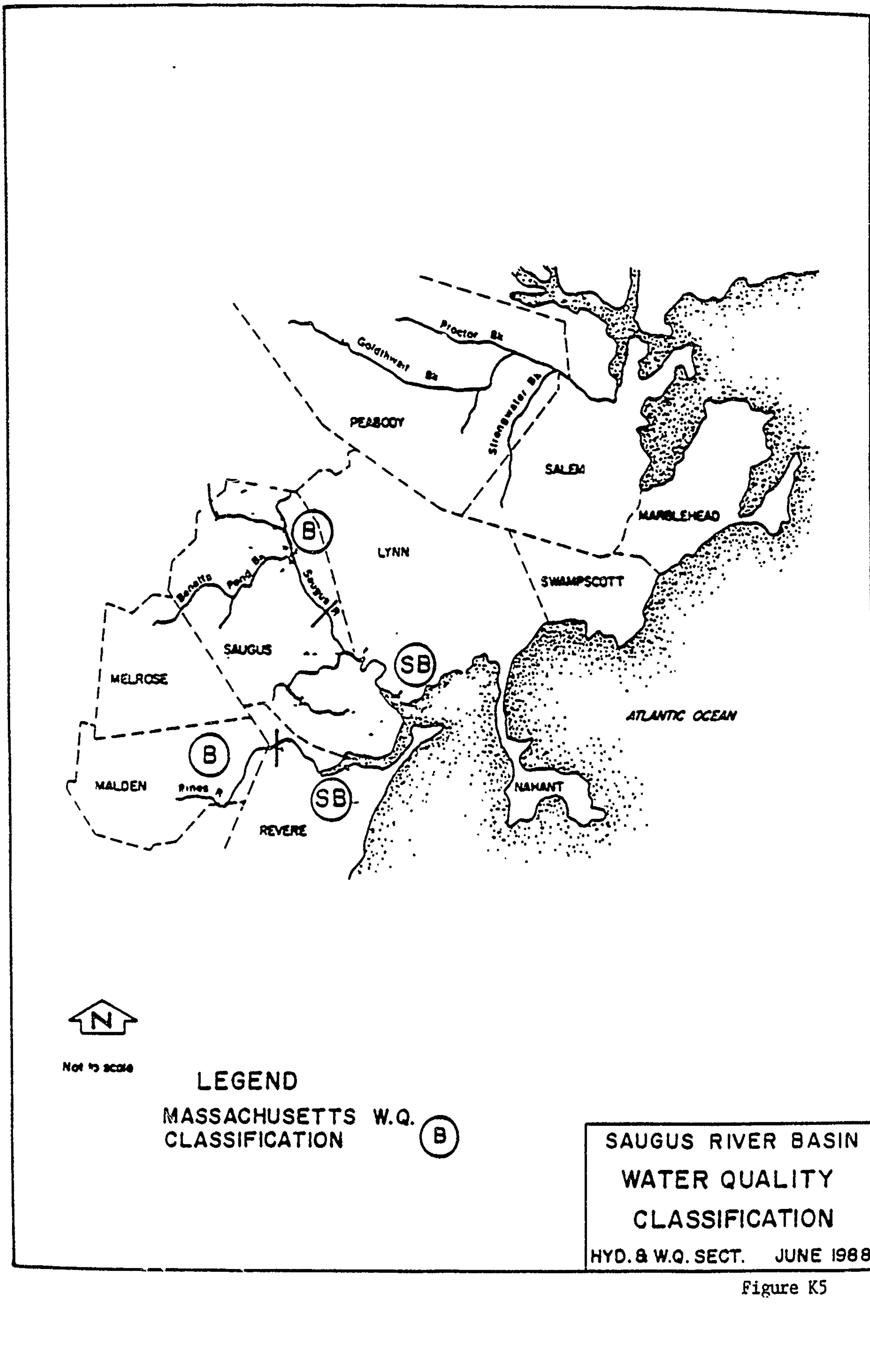
General

The inland waters of the Saugus and Pines Rivers have been designated class B and the coastal waters of these rivers have been designated class SB by the Massachusetts Division of Water Pollution Control (MDWPC) (see Figure K5). Class B waters are suitable for swimming, other recreation and for protection and propagation of fish, other aquatic life and wildlife. Class SB waters, in addition to those designated uses as described for class B waters, are suitable for shellfish harvesting with depuration. Shellfishing is the most sensitive activity in the coastal area due to the stringent controls established to prevent human consumption of contaminated clams and other bivalves.

According to the "Saugus River Basin Water Quality Survey" prepared by the MDWPC in November, 1982, water quality in the Saugus and Pines Rivers Estuary generally meets class standards during dry weather flow with a few minor violations occurring from high coliform counts caused by combined sewers, illegal sewer connections and failing septic systems. During storm events, however, discharges from storm drains and overland flow have a significant adverse impact on water quality in the upper estuary (above the Route 107 bridge) principally because these discharges make up a larger percentage of the water volume during these events. Dissolved oxygen levels are impacted by the high quantities of BOD discharged. Coliform levels are also extremely high. In the lower estuary (below the Route 107 bridge), the BOD levels do not have as severe an impact due to the greater volume of water involved in the tidal interchange. However, coliform levels are high enough that during low tides standards are consistently exceeded even in the downstream area during high runoff events. Because of the high coliform levels in the estuary, the mudflats within the estuary have not been classified open for shell-fishing in recent years, although a few areas have been classified as restricted, whereby licensed Master Diggers and their employees may harvest shellfish and then have them depurated at the shellfish purification plant in Newburyport, MA.

Results of the 1982 MDWPC testing for cadmium, chromium, mercury and zinc show that concentrations in the lower estuary, downstream from the Route 107 bridges, generally meet the latest Water Quality Criteria (1986) established by EPA. Results of sampling by the Corps at various times from 1982 to 1986, however, show some problems with a number of heavy metals.

Detailed water quality data may be found in the Water Quality Appendix.



PEABODY
Proctor Bk
Goldthwait Bk
Strongwater Bk
SALEM
MARBLEHEAD
LYNN
SWAMPSCOTT
Saugus R
SAUGUS
MELROSE
MALDEN
Rines R
REVERE
NAHANT
ATLANTIC OCEAN
B
SB
B
SB
N
Not to scale
LEGEND
MASSACHUSETTS W.Q.
CLASSIFICATION
B
SAUGUS RIVER BASIN
WATER QUALITY
CLASSIFICATION
HYD. & W.Q. SECT. JUNE 1988

Figure K5

Major Pollution Sources

There have been several pollution sources identified within the estuary: three thermal water discharges - General Electric River Works Plant (31 discharge locations), RESCO Plant and Eastern Tool Manufacturing Company (one pipe each); one intermittent discharge from Lynn's combined sewer overflow; and one leachate from the Saugus landfill.

Permitted thermal discharges allowed to the three companies amount to over 160 million gallons/day (mgd), although the most that would generally be discharged concurrently would be less than 100 mgd (115 cfs). The locations of all discharges, except Eastern Tool Company's, are between Route 107 and the General Edwards Bridge on the Saugus River.

The combined sewer overflow (CSO) at Summer Street in Lynn discharges an estimated 40 to 50 times a year into the Saugus River during times when rainfall intensity is more than 0.1 inch/hour. Annual loadings estimated for the Lynn CSO include: Flow - 160 million gallons/year, BOD - 95,000 pounds (lb)/year, Total Solids - 467,000 lb/year, Total Kjeldahl Nitrogen - 19,000 lb/year, Ammonia Nitrogen - 6,000 lb/year and Phosphorus - 4,000 lb/year. The Lynn Water and Sewer Commission has engaged a consultant to correct the problem. Preliminary plans call for removing the CSO from the Saugus River through separation of sewers.

A potential major nonpoint source within the estuary is the landfill area located in the salt marsh near the junction of the Pines and Saugus Rivers. This landfill area is comprised of four major sites: the former Daggett and Dematteo (Saugus) landfill, which occupies almost 200 acres, the RESCO facility which covers approximately 100 acres, the RESCO ash landfill which covers approximately 11 acres, and the GE landfill which covers approximately 10 acres. The entire landfill area is bounded by the Boston and Maine Rapid Transit Line on the east, State Route 107 on the west and the marsh areas of the Saugus and Pines Rivers on the north and south.

Numerous investigations of the landfill have been undertaken; however, the majority studied only the Saugus landfill and took place before the RESCO Plant began operating in 1975. As described in the Environmental Impact Report on the Saugus Landfill Project, heavy metals, nutrients and polychlorinated biphenyls (PCB's) were found to leach from the landfill but quickly settled out or were absorbed in the marsh muds within 100 to 400 feet downstream from the landfill. RESCO is currently involved in a consent agreement with DEQE. One requirement of that agreement is that an assessment of the environmental impacts of handling, storage and the use of ash as a grading material be conducted. RESCO has hired a consultant who is in the process of developing a scope of work to address all the major concerns.

Water Quality Parameters

Unless otherwise noted all data in the following sections pertains to the estuary of the Saugus and Pines Rivers.

Water Temperature

Since tidal movement dominates the water flow within the estuary, water temperatures are generally the same as the ocean temperatures which exist in Broad Sound. Temperatures in Broad Sound generally range from the low 30's during mid winter to the low to mid 70's during late summer. The releases made from the industries along the lower Saugus River, as described in their National Pollutant Discharge Elimination System (NPDES) Permits, are small in comparison to the natural tidal flushing volume, and temperature rise in the farfield areas is negligible. From analysis completed by General Electric and RESCO as part of their Permit requirements, temperatures reduce to less than 2^{o} Fahrenheit change less than a few hundred feet from the point of discharge.

Salinity

As a result of the sluggish flow from the large upstream wetlands and ponding areas, the freshwater volume entering the tidally influenced portion of the Saugus and Pines Rivers is a small component of the estuarine volume. The saltwater-freshwater ratio for various runoff conditions is given in Table K4.

From water quality data collected within the estuary by the Corps of Engineers, and by RESCO as part of their NPDES Permit requirement, there appears to be nearly complete top to bottom mixing of salinity with freshwater from the mouth of the Saugus River up to the Lincoln Avenue bridge and from the mouth of the Pines River to its upper end at the Town Line Brook tide gate. Further upstream on the Saugus River, minor density stratification does occur. The upper limit of salinity is at the Saugus Iron Works historical site northern boundary line on the Saugus River, the Central Street Bridge on Shute Brook and the Town Line Brook tide gate on the Pines River. The highest salinity levels occur at the mouth of the Saugus River, ranging from 29 to 33 ppt.

Dissolved Oxygen

Dissolved oxygen (DO) levels were measured in the estuary during low and high tide conditions by the Corps in 1986 and by the MDWPC in 1982. The results generally show that during extreme low tide conditions there is a low DO problem in the Saugus and Pines Rivers above Route 107. During high tide measurements, most areas meet the minimum 6 mg/l State criteria with the exception of the upper Pines River and upper Diamond Creek area. It is unknown at the present time what causes the low dissolved oxygen; however, benthic organism interaction with built-up organic sediments may be a significant problem. Also, algae buildup in the upper portions of the Saugus and Pines Rivers may cause DO depletion during summer weather. Data collected during wet weather in 1987, by Camp, Dresser and McKee, the consultant working on Lynn's combined sewer overflow for the Lynn Water and Sewer Commission (1988), shows that there are significant amounts of organic matter being released from storm drains and combined sewers which accumulate in the sediments causing DO depletion as they decay.

TABLE K4

SALTWATER-FRESHWATER FLOW RATES
(ESTIMATED FOR SAUGUS RIVER
AT GENERAL EDWARDS BRIDGE)

Freshwater Peak Flow Rate (cfs)	Percent Chance of Occurrence	Average Tidal Flow Rate for Mean Tide Range (cfs)	Saltwater to Freshwater Flow Ratio
850	50 (2-yr event)	9,400	11.1
1,900	10 (10-yr event)	9,400	4.9
3,300	2 (50-yr event)	9,400	2.8
4,000	1 (100-yr event)	9,400	2.4

NOTES: 1. Peak flow rates were obtained by statistical analysis of the Aberjona River USGS gage at Winchester, MA for the upper watershed and adopted lower watershed discharges, assuming the two peaks coincident. This flow rate does not necessarily last for 6 hours (1/2 of a tide cycle).

2. Average tidal flow rate is obtained by taking the tidal volume exchanged in a complete tide cycle and dividing by 6 hours.

pH

According to the 1986 Corps data, those areas inundated by large amounts of saltwater have high pH, generally above 7, and rising as high as 8 standard units (SU). Low pH levels, slightly below the State criteria of 6.5 SU, occur in the freshwater-dominated upper areas of the Saugus and Pines Rivers and in the small streams that drain into the estuary during times of low tide. The low pH is due primarily to natural processes since there are no major industrial discharges in the upper basin.

Turbidity and Apparent Color

Turbidity values measured by the Corps in 1986 throughout the estuary were low, ranging from 0.8 to 4 Jackson Turbidity Units (JTU). Apparent color levels show significantly more variation ranging from five standard units (SU) up to 40 SU; the highest levels occur in the upper estuary during dead low tide when the water column is almost entirely freshwater.

Suspended Solids

According to the 1986 Corps data, suspended solids content within the water column is low throughout the tide cycle with values ranging from 7 to 31 mg/l. Solids concentrations averaged 13 mg/l and the volatile portion averaged about 3 mg/l. There was no significant variation from top to bottom within the estuary indicating that there was only a minor amount of suspended sediment moving along the bottom. The largest difference between the surface and bottom values occurred near the General Edwards Bridge where the constriction caused by bridge piers resulted in higher velocities and more suspended solids moving near the bottom of the channel.

Nutrients

Data collected in 1986 by the Corps in the estuary indicates that phosphorous levels ranged from 0.03 mg/l to 0.15 mg/l, nitrate/nitrite levels ranged from 0.045 mg/l to 0.75 mg/l and ammonia levels ranged from 0.04 mg/l to 0.61 mg/l. The higher concentrations occurred at low tide at the upper ends of the estuary where man's influence in the freshwater watershed increased the concentrations most strongly. Camp, Dresser and McKee, the consultant investigating Lynn's combined sewer overflow has found that a significant source of nutrients is the Summer Street combined sewer overflow.

Biological Oxygen Demand (BOD)

Analysis of samples collected during dry weather conditions indicate that there are only minor amounts of BOD present in the water column (less than 2 mg/l). More significant amounts have been recorded during wet weather conditions by the MDWPC and by Camp, Dresser and McKee as a result of storm drainage and combined sewer discharges.

Contaminants

Metals

Grab water column samples have been collected at various times by the Corps of Engineers during the period 1982-1986. The results showed that there were a number of metals exceeding EPA's chronic criteria to protect sensitive marine aquatic life although the less stringent acute criteria were usually met. Mercury appears to exceed the chronic criteria frequently while other metals showing occasional exceedances include copper, zinc, lead and nickel. Acute criteria is also occasionally exceeded by copper. It is unknown what effects, if any, these elevated levels are having on the estuarine environment and its organisms. These results are in contrast to 1982 MDWPC testing for cadmium, chromium, mercury and zinc that showed concentrations in the lower estuary, downstream from the Route 107 bridges, to generally meet the 1986 EPA Quality Criteria for water.

Oil and Grease

Oil and grease measurements were collected during low and high tide conditions throughout the estuary. In general, the levels of oil and grease are low, less than 1 mg/l, with a few exceptions which could have occurred as a result of minor spills from one of the commercial boats or marinas located upstream. It is unlikely that this is a continuous source since Standard EPA elutriate tests were also completed by the Corps on sediments taken from throughout the proposed channels for the Saugus and Pines River Navigation Studies, and these results generally show oil and grease concentrations of less than 1 mg/l, with 12 mg/l being the most ever measured.

Coliform Bacteria

The highest coliform bacteria levels occur during wet weather conditions as storm drains, combined sewer overflows and overland flow cause exceedances of State saltwater criteria throughout the estuary.

Dry weather flow measurements taken by the Corps on August 20, 1986 show that coliform levels which cause minor exceedances of State saltwater criteria generally occur at the upper ends of the tidally influenced portions of the water body during a low tide condition. It appears, as suggested by the MDWPC, that direct sewage overflows or defective septic systems are draining into Shute Brook, upper Diamond Creek, Town Line Brook and possibly the Saugus River above the Lincoln Avenue bridge. From analysis of the Corps data, values throughout the estuary ranged from 30 to 11,000 colonies/100 ml for total coliform and from 2 to 1,100 colonies/100 ml for fecal coliform. During high tides, coliform levels are diluted significantly such that State saltwater criteria were met at almost all stations during the Corps measurements.

F. Sedimentology

Information concerning the physical and chemical charactertistics of aquatic sediments from the Study Area is available from a number of sources.

These include previous Corps of Engineers' studies of the Saugus and Pines Rivers and Lynn Harbor (USACE 1985b, 1986), studies of the Saugus Landfill and information contained in NED Regulatory Branch and Materials and Water Quality Laboratory files. For this study, surficial (Ponar grab) samples were taken for grain size analysis in January of 1988 from the vicinity of alternative floodgate alignments and along the Lynn Harbor shorefront by the Corps (see Figure K6). Two additional samples taken by the Corps (4a and 6a, collected in March of 1988) had relatively high (10 -15%) silt content, and were also analyzed for chemical contaminants (i.e. heavy metals, PCBs and petroleum hydrocarbons). Qualitative information concerning sediments from various habitats sampled in conjunction with benthic invertebrate and plant community studies by IEP, Inc. (1988) was also obtained.

Physical Characteristics

Lynn Harbor and the Lower Saugus River

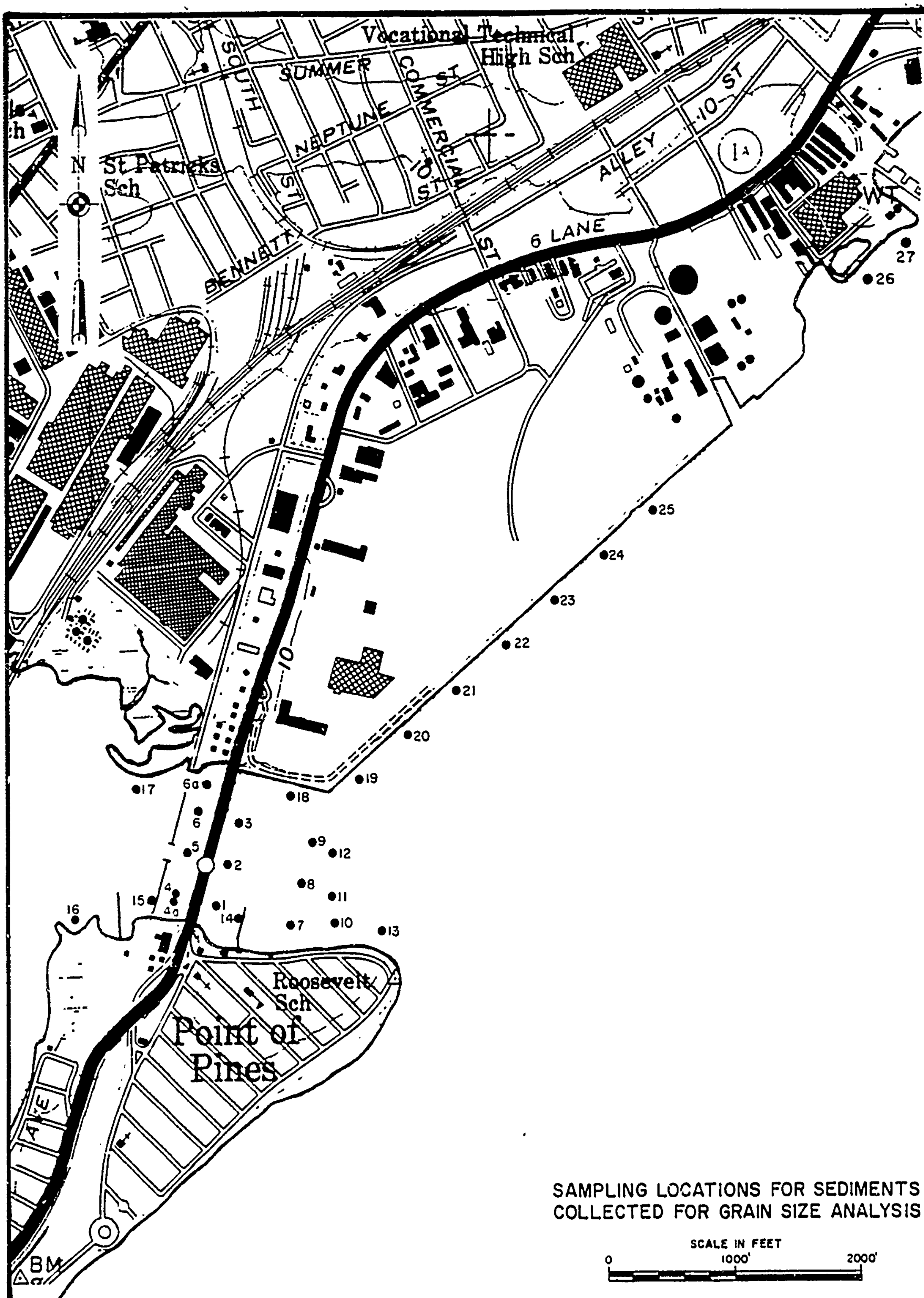
Lynn Harbor bottom sediments consist primarily of fine sands and silts. The sediments are derived from fluvial deposits from the Pines and Saugus Rivers, and from glacially derived deposits that underlie the harbor. Extensive mussel beds are present in shallower areas of the harbor, and boulder fields and bedrock outcrops occur in several locations (Chesmore et al., 1972).

Results of grain size analysis for sediments collected from Lynn Harbor and the lower Saugus River in this Study are summarized in Table K5. Sediments in the vicinity of the alternative floodgate alignments ranged in texture from fine-grained silty sands to gravelly sand. Subtidal samples generally contained <5% fines (silt and clay). Failure to obtain samples using a Ponar dredge in some areas (samples 2,4,6,8,13,14) suggest that tidal scour has removed unconsolidated sediments in these locations. Substrates in these areas are presumably either hard packed sands or rock. Intertidal sediments from two locations just west of the General Edwards Bridge (samples 4a and 6a) were fine silty sands containing 10.4 and 13.8% fines. Intertidal sediments in the vicinity of the bridge contain bricks, broken glass and other debris. Intertidal sediments along the Lynn Harbor bulkhead (samples 18 - 25) were medium to fine sands containing less than 3% fines (mean = 1.8%). Sediments from the Lynn Harbor shorefront near the Norelco plant (samples 26 - 27) were sands containing a mean of 6.8% fines.

Previous studies (USACE, 1986) indicate that sediments from the western navigation channel in Lynn Harbor are mostly sands or silty sands containing an average of 7.6% fines. A sample from the center of the river, near Alignment 2, was gravelly sand with a fines content of 0.5%.

Qualitative information concerning sediments in Lynn Harbor is available from various studies. Borings taken across the breadth of the Saugus River in 1934 indicate that surficial sediments near the present location of the General Edwards Bridge are primarily silty sands.

Surficial sand deposits ranged in depth from approximately 5 to 20 feet, and were typically underlain by blue clay. Near the southern (Revere)



Vocational Technical
High Sch
SOUTH
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Pines
AVE
BM
SAMPLING LOCATIONS FOR SEDIMENTS
COLLECTED FOR GRAIN SIZE ANALYSIS
SCALE IN FEET
0
1000'
2000'

FIGURE K6

Table K5. Results of grain size analysis of surface sediments from Lynn Harbor and the lower Saugus River.

Location/Sample Number[1]	Habitat[2]	Grain Size Distribution[3] % Gravel	% Sand	% Fines	Median Grain Size (mm)
Vicinity of Floodgates					
Alignment 1					
10	S	6.1	93.2	0.7	0.37
11	S	17.4	81.5	1.1	1.00
12	S		89.0	11.0	0.13
Alignment 2					
7	S		99.0	1.0	0.19
8	S		n.s.		
9	S	17.7	78.0	4.3	0.64
Alignment 3					
1	S	2.2	95.2	2.6	0.25
2	S		n.s.		
3	S	1.5	95.5	3.0	0.22
Alignment 4					
4a	I		89.6	10.4	0.17
4	S		n.s.		
5	S	2.9	96.2	0.9	0.49
6	S		n.s		
6a	I		86.2	13.8	0.15
Confluence of Saugus and Pines Rivers					
15	S	17.5	80.1	2.4	0.22
16	S	60.1	39.4	0.5	7.04
17	S	2.0	92.8	5.2	0.27
Lynn Harbor Shorefront					
Bulkhead Area					
18	I		98.0	2.0	0.22
19	I	1.0	97.6	1.4	0.24
20	I	0.8	97.4	1.8	0.22
21	I	0.4	98.0	1.5	0.20
22	I		97.6	2.4	0.19
23	I		97.7	2.3	0.20
24	I	18.6	80.1	1.3	0.30
25 a	I	0.8	97.2	2.0	0.58
25 b		28.0	72.0		0.32
Inner Harbor					
26	I	1.8	94.0	4.3	0.32
27	I	1.0	89.7	9.3	0.22

notes:

1. see Figure K6 for locations of sample sites; All samples except 4a and 6a were collected in January of 1988. Locations 4a and 6a were sampled in March, 1988.
2. S: subtidal locations; I: intertidal locations.
3. "Fines" include silts and clays passing through a # 200 U.S. Std. Sieve.
   n.s: hard substrate, no sample obtained via Ponar grab for grain size analysis.
4. All samples were collected and analyzed by NED, Corps of Engineers.

shoreline surficial sand deposits were underlain by peat at depths ranging from ca. -15 to - 27 feet NGVD. Recent borings from two locations along the Lynn bulkhead (ca. 2000 feet northeast of the MDC fishing pier) revealed 10 to 23 feet deep sand deposits underlain by clay. A boring in the vicinity of the Point of Pines Yacht Club anchorage indicates that surficial sands are approximately 8 feet deep (NED 1983 Regulatory Files).

IEP, Inc. provided additional information to the Corps, in association with its 1987 sampling program for this Study. Intertidal samples from a transect taken off Point of Pines near floodgate Alignment 2 were sands. Intertidal samples from the vicinity of floodgate Alignment 5 were silts or fine sands. Subtidal sediments near the vicinity of floodgate Alignments 1 and 3 were classified as silty sands or sandy silts. Intertidal samples from stations near the Lynn Harbor bulkhead were silty sands or sands.

Saugus and Pines Rivers

Subtidal samples from near the confluence of the Pines and Saugus Rivers are sands with relatively low (0.5 - 5.2%) fines content.

Sediments in the Saugus River upstream of its confluence with the Pines River are primarily sandy, peaty or clayey silts (IEP, INc., 1988; USACE, 1986). Percent fines in surficial and core samples collected in 1982-1984 from upstream of the confluence with the Pines River averaged approximately 60% (USACE, 1986).

Subtidal sediments in the Pines River range from coarse to fine sands with low (< 2.0%) fines content to silts (USACE, 1985b). Intertidal sediments in the Pines River are predominantly silts (IEP, Inc., 1988; USACE, 1985b).

Emergent Wetlands

Emergent wetland is the predominant habitat type in the Saugus/Pines Rivers Estuary (IEP, Inc., 1988). Soils are mostly highly decomposed sapric histosols (organic soils) or organic rich mineral soils. Mean organic content was 22% in salt marsh transects and 28% in transects from mixohaline communities in the Upper Saugus River and Shute Brook. A substantial proportion of the presettlement emergent wetland habitat within the estuary has been filled.

Bulk Chemistry

Lynn Harbor and the Lower Saugus River

Two sediment samples from the vicinity of the General Edwards Bridge with relatively high percent fines content were analyzed for metals, petroleum hydrocarbons, PCB's, and priority pollutants (see Table K6A). With the exception of nickel, concentrations of metals were low. Elevated concentrations of nickel may have resulted from bridge repair activities in progress at the time of sampling. Concentrations of PCB's and petroleum hydrocarbons were also low. The priority pollutant scan yielded

detectable concentrations of only one compound, the plasticizer bis (2 ethylhexyl) phthalate, which likely resulted from laboratory contamination.

Little other information is available concerning the bulk chemistry of Lynn Harbor sediments. Sand sampled from the vicinity of proposed floodgate Alignments 2 and 3 in 1981 contained very low levels of lead (< 10 ppb), cadmium (< 5 ppb) and other heavy metals (NED 1983 Regulatory Files). Silty sediments (mean % fines = 71%) from the eastern Lynn Harbor navigation channel (near Nahant Beach) are, however, contaminated with high (Category III) levels of cadmium (NED 1981 Materials Lab Files). Elevated levels of arsenic, lead, chromium, copper and nickel also occur in these sediments.

Saugus and Pines Rivers

Results of previous Corps (USACE 1985b, 1986) bulk chemical analysis of Saugus and Pines River sediments are summarized in Table K6B. Based on average concentrations of heavy metals, PCBs and oil and grease, Saugus/Pines Estuary sediments can generally be classified as Category I sediments according to Massachusetts State guidelines (see Barr, 1987). Individual samples, however, frequently contained elevated (Category II) levels of chromium, mercury, cadmium and/or zinc. Highest levels of lead, zinc, chromium, copper and nickel were noted from a single sample in the Saugus River and may be attributed to contamination from a nearby junkyard (USACE, 1986).

Limited information concerning contaminant concentrations in Saugus River sediments is also available from NED Regulatory Branch files (1986). Samples collected in 1983 from the vicinity of industrial facilities in the lower Saugus River (below Route 107) contained elevated (Category II) levels of chromium and lead and high (Category III) levels of oil and grease.

Table K6A. Results of bulk chemical analysis of selected Saugus River sediments from just west or the General Edwards Bridge.[a]

Constituent	Sample 4a	6a
Metals (ppm)		
Mercury	nd	0.49
Lead	nd	nd
Zinc	31	63
Arsenic	nd	2.0
Cadmium	2	nd
Chromium	11	21
Copper	nd	20
Nickel	131	167
PCB's (ppb)	10	20
Petroleum Hydrocarbons (ppm)	50	150
Priority Pollutants		
bis (2 ethylhexyl) phthalate (ppm)	8[b]	13[b]
Percent Fines	10.4	13.8

[a] Samples were collected in March of 1988; see Figure K6 for sample locations.

[b] Likely a result of laboratory contamination.
nd means below instrument detection limits.

Table K6B. Summary of previous Corps bulk chemical analysis of Saugus River and Pines River sediments.[a]

Parameter	Concentration[b] range	mean	Classification[c] range	mean
Saugus River				
Mercury	0.2 - 0.7	0.52	I-II	
Lead	<18 - 320	<105	I-III	II
Zinc	40 - 336	154	I-II	I
Arsenic	<1 - 9	<5.0	I	I
Cadmium	<2 - 10	<4.7	I-II	I
Chromium	<3 - 224	<121	I-II	II
Copper	<4 - 126	<54	I	I
Nickel	<20 - 27	<21	I	I
Oil & Grease	<120 - 2200	<1020	I	I
PCB (ppb; n=6)	<10 - 36	<100	I	I
Pines River				
Mercury	0.11- 0.15	0.13	I	I
Lead (n=2)	<19 - 111	<56	I-II	I
Zinc	25 - 84	53	I	I
Arsenic	0.9 - 1.4	1.2	I	I
Cadmium	<2 - 4	<2.5	I	I
Chromium	<19 - 85	<50	I	I
Copper	<4 - 27	<13	I	I
Nickel	<45	-	I	I
Oil and Grease	11 - 657	251	I	I
PCB (ppb)	<10 - 46	<24	I	I

[a] This table is adapted from USACE, 1985b, 1986; Samples were obtained from 1982 to 1986.

[b] All values in ppm unless otherwise noted. Unless noted sample size (n) = 9 for Saugus River and 4 for Pines River.

[c] Classification based on Massachusetts DEQE-DWPC guidelines for dredged material (Barr, 1987).

Emergent Wetlands

Little information exists concerning the bulk chemistry of wetland soils in the Saugus Estuary. Marsh sediments in urbanized estuaries typically, however, contain elevated concentrations of heavy metals, PCB's, PAH's and other anthropogenic contaminants. Highest concentrations of contaminants in Saugus/Pines marsh soils probably occur in the vicinity of the Saugus, RESCO and GE landfills. Heavy metals (including cadmium, copper, chromium, nickel, lead, zinc and mercury), nutrients and PCBs are leaching from these areas into adjacent marsh and tidal creeks.

Transport Patterns

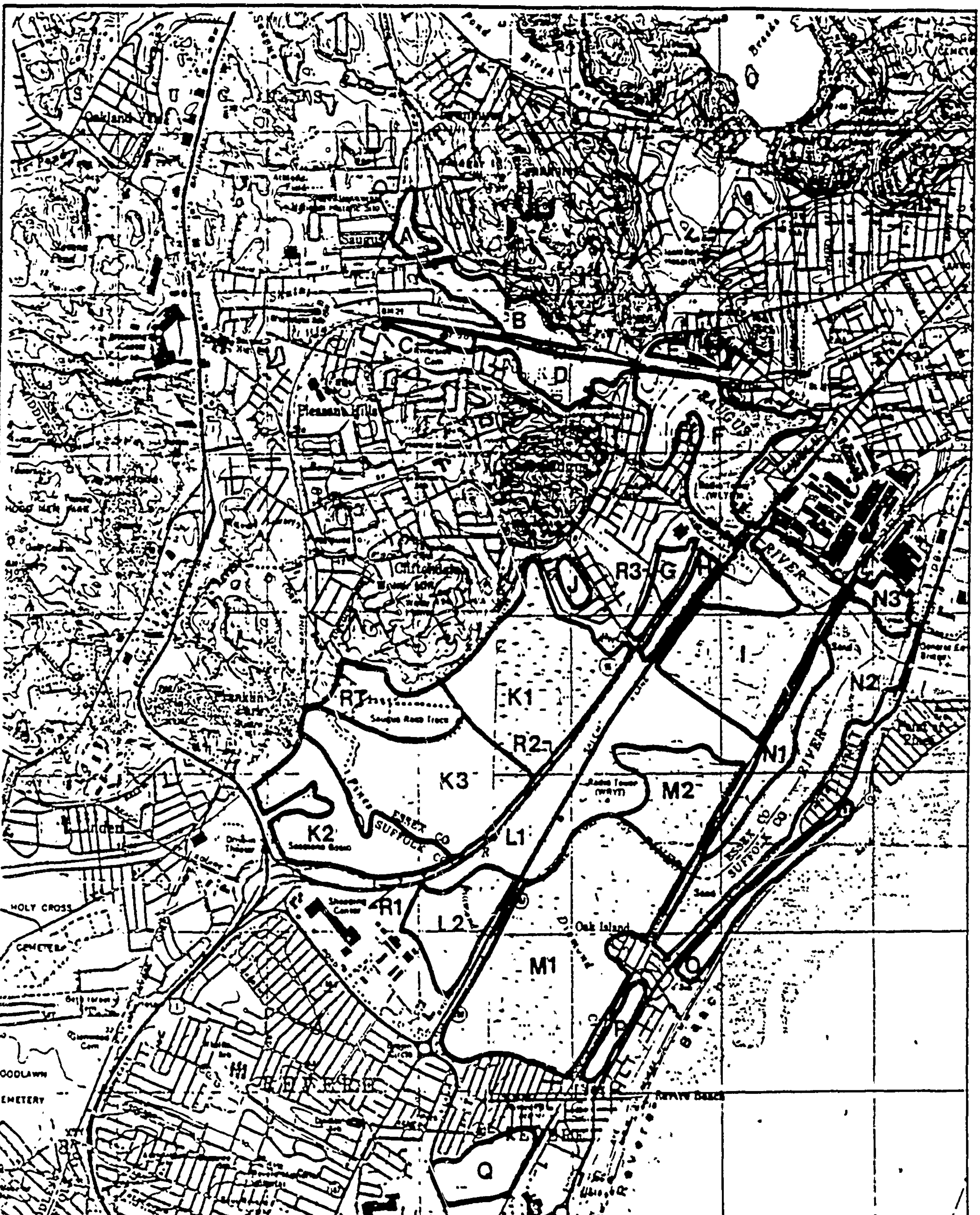
Suspended solids analyses indicate that any down-stream migration of sediment from the upper basin is minimal during low freshwater flow conditions because of hydrologically slow basin characteristics (short stream lengths interconnected by large wetland areas). It is likely that if there is any movement of solids from the upper freshwater basin into the estuary, it takes place during major freshwater runoff events. Once sediment reaches the upper estuary, it settles out, since the estuary has such a flat stream gradient and is much wider than the freshwater stream. Erosion and sedimentation in the estuary is controlled by tidal fluctuations. There was very little sediment movement measured in the estuary during a normal tide range condition (tide range 10.6 feet on flood, 9.8 feet on ebb) observed by the Corps. If suspended solids concentrations resulting from sediment movement are significant at all, they would be observed during a major tidal storm event. Other conclusions based on current and tidal measurements by the Corps are: (1) sediment movement in both the Pines and Saugus Rivers upstream from Route 107 is not as significant as that downstream since there are restrictive bridge openings in this area which dampen rapid tidal changes, and (2) sediment accretes in the overbank areas and at the inside of bends because of the significant reduction in velocity which takes place there.

Sediment accretion at the mouth of the Saugus River near Point of Pines has also been noted from discussions with long term residents. Sediment seems to be accumulating at the mouth of the Saugus River as a result of the northerly movement of material along Revere Beach (littoral process) rather than from outward transport from the river.

G. Cover Maps

General

Within the Study Area inland (west) of the General Edwards Bridge, estuarine wetland types include deepwater habitat (i.e., below the elevation of extreme low water of spring tide), subtidal unconsolidated bed and aquatic bed habitats, and intertidal aquatic bed, unconsolidated shore, and emergent wetland habitats (Cowardin et al., 1979). The latter class, with the dominance type of saltmeadow grass (*Spartina patens*), is by far the most extensive community type within the wetland of the Study Area. In order to facilitate the characterization of different portions of the Study Area wetland, the wetland was divided into compartments as shown in Figure K7.



SCALE:
1" = 2083'

SAUGUS / PINES RIVERS
ESTUARINE WETLANDS STUDY

WETLAND STUDY
COMPARTMENTS

Figure K7

These compartments are referenced throughout the text. They are generally composed of areas separated from each other by roads and railroad lines. Some compartments are separated into smaller areas by river boundaries or arbitrary lines (e.g. Compartment K: K1, K2, K3) so that more specific areas of the marsh can be referenced.

Methods Used to Produce Maps

Cover maps were prepared to show the major wetland community types within the Study Area (Plates 1 through 6[1]). The initial step in producing these maps was the interpretation of color infrared aerial photographs taken May 18, 1987 at a scale of 1" = 500'. Following initial field reconnaissance to relate tone and texture patterns on the photos to community types in the field, cover types were delineated and classified on the photographs. All delineations were subsequently field checked again and necessary adjustments were made in the delineations to reflect observed conditions.

Base maps of the Study Area were produced by photographic expansion of USGS 1:25,000 topographic maps to a scale of 1" = 500', and then deriving a mylar base containing only selected features from the USGS maps. Cover-typed delineations on the aerial photographs were then transferred directly to the base maps. Finally, the acreages of the various community types were determined using a computer-based digitizer. The 500' scale maps were then photographically adapted to produce Plates ´ through 6.

Description of Community Types

Introduction

The community types defined and delineated for the cover maps of the Study Area primarily reflect the hydrologic regime and vegetative species composition which dominate within each unit. As outlined in Table K7, the initial classification relates to the water regime of the wetland as defined by Cowardin et al. (1979). Tidal wetland portions of the Study Area are distinguished as follows:

- subtidal (permanently flooded with tidal water);
- irregularly exposed (land surface is exposed by tides less often than daily);
- regularly flooded (tidal water alternately floods and exposes the land surface at least once daily);
- irregularly flooded (tidal water floods the land surface less often than daily); or
- seasonally flooded freshwater.

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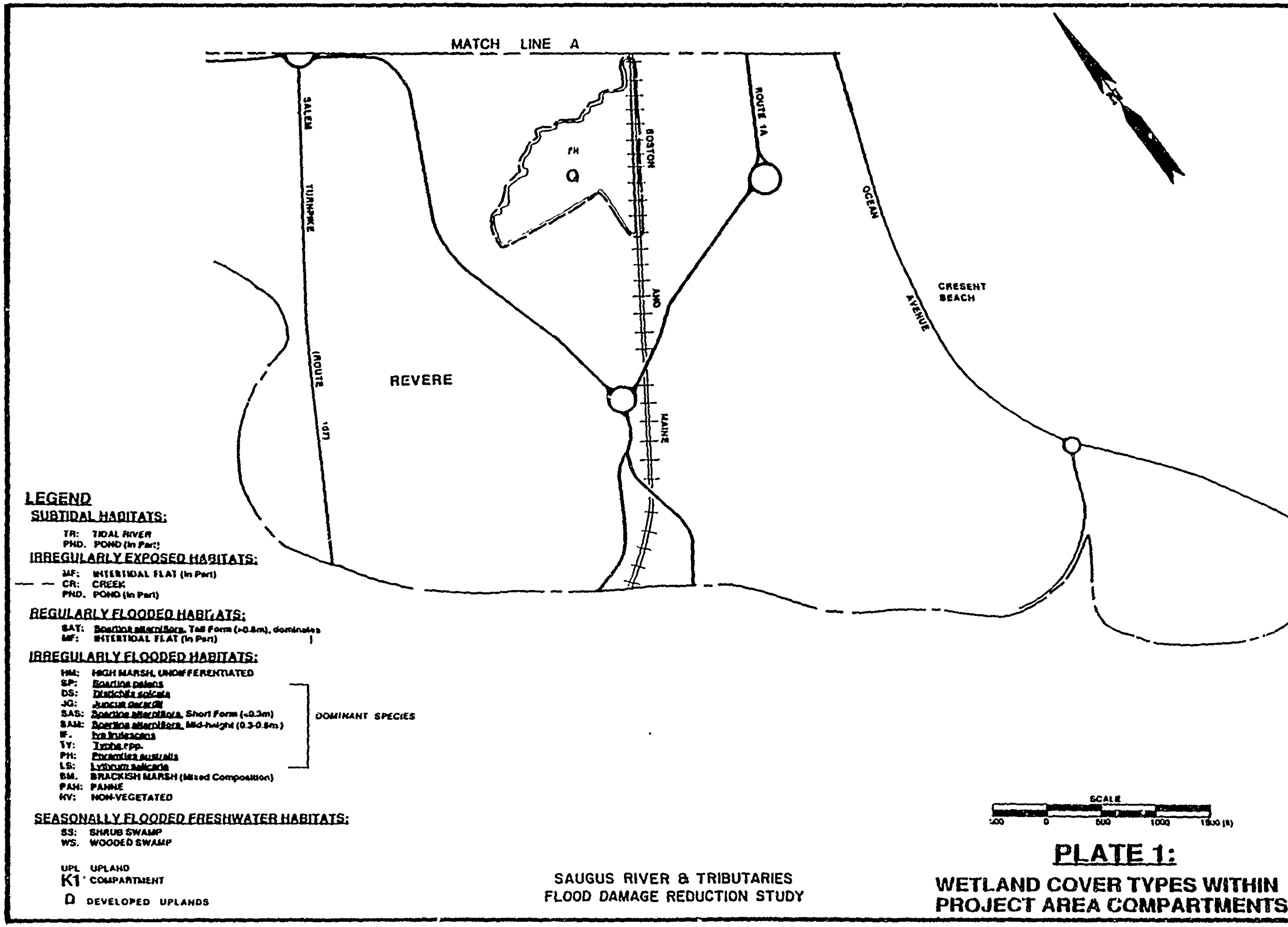
[1]Plates 1 through 6 are available in much enlarged size. Copies may be requested from the New England Division, Corps of Engineers.



SAUGUS RIVER & TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

PLATE 1:

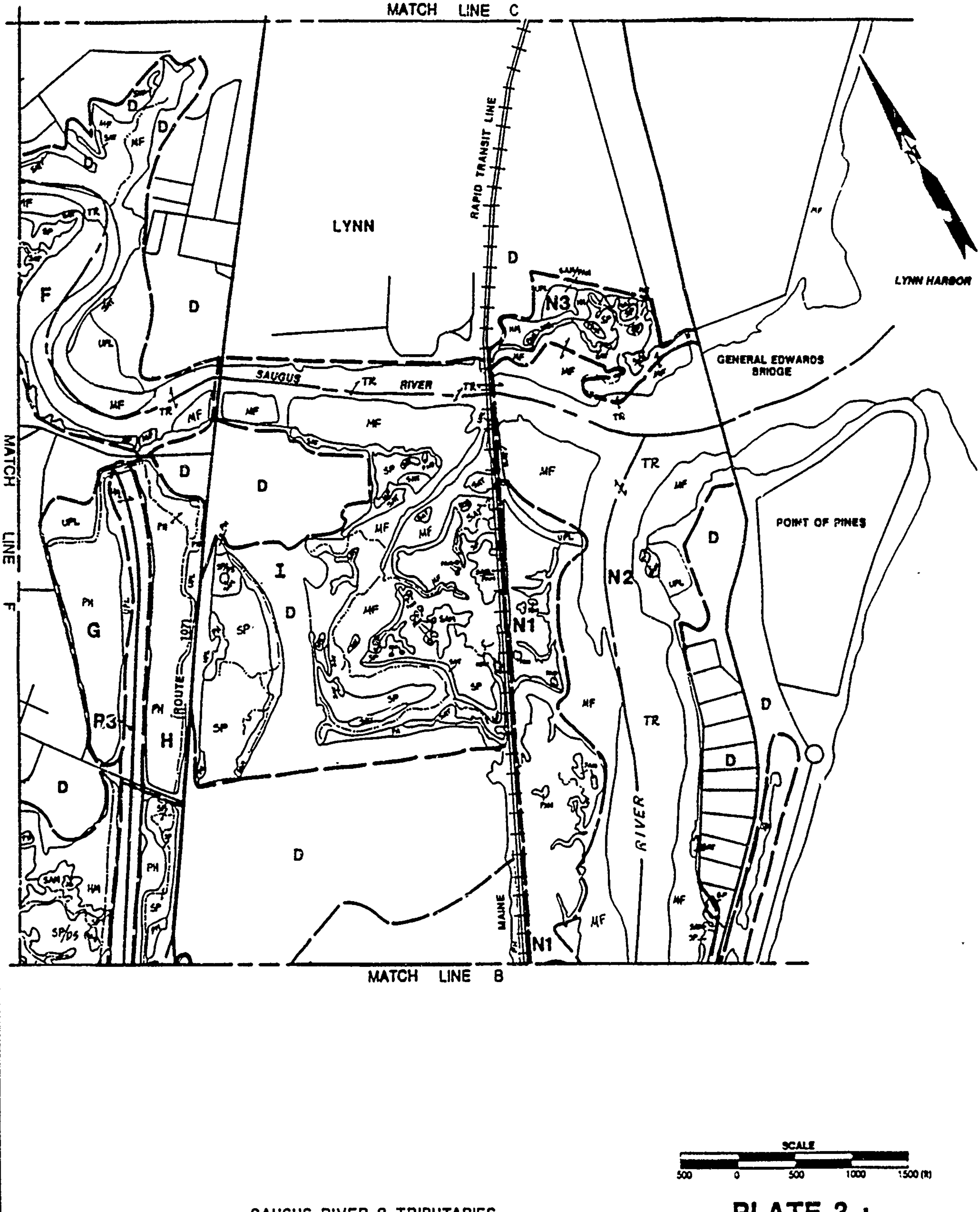
WETLAND COVER TYPES WITHIN PROJECT AREA COMPARTMENTS

SAUGUS RIVER & TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

NOTE:
1 REFER TO PLATE 1 FOR LEGEND

PLATE 2 :

WETLAND COVER TYPES WITHIN PROJECT AREA COMPARTMENTS

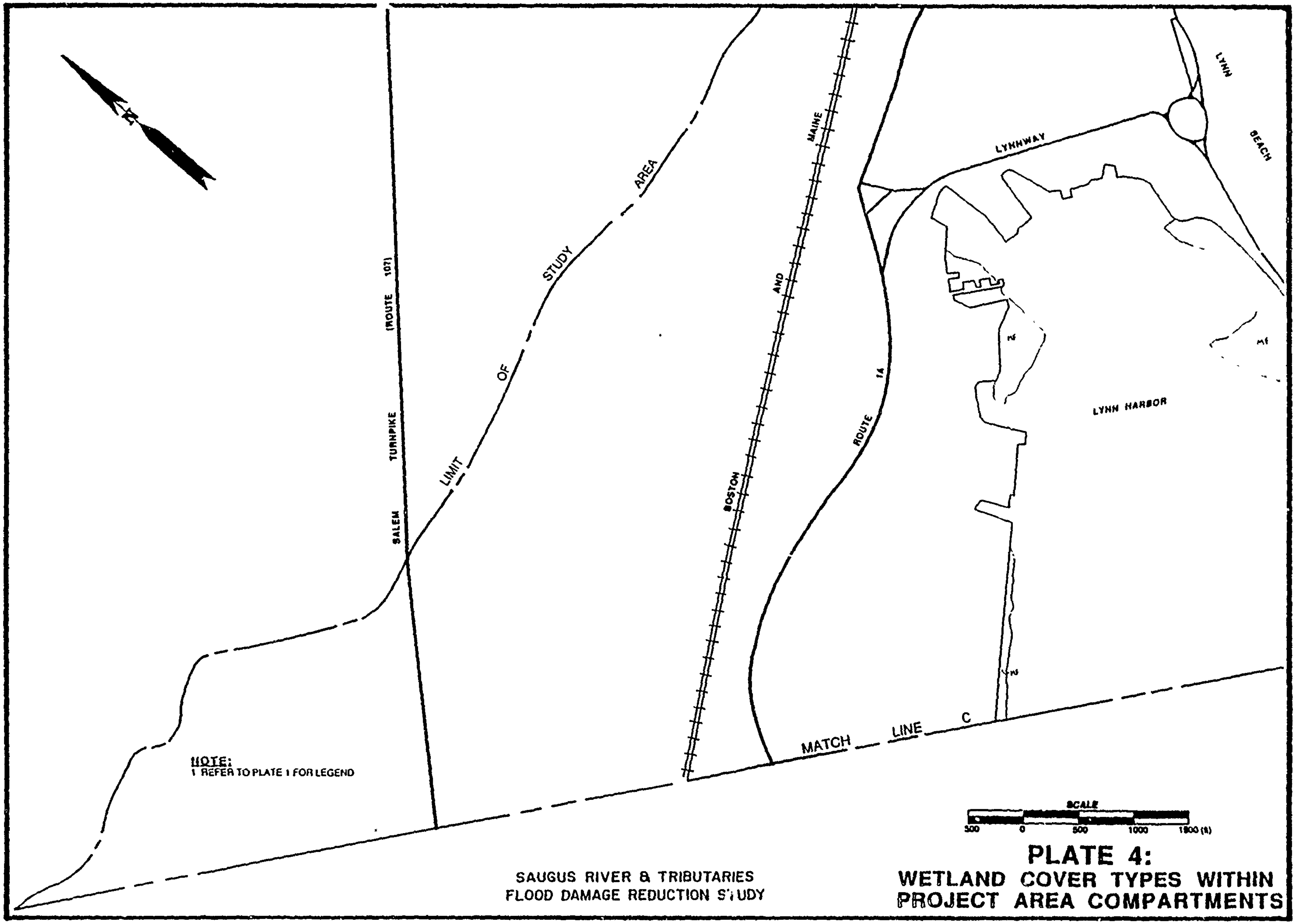


SAUGUS RIVER & TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

NOTE:
1 REFER TO PLATE 1 FOR LEGEND

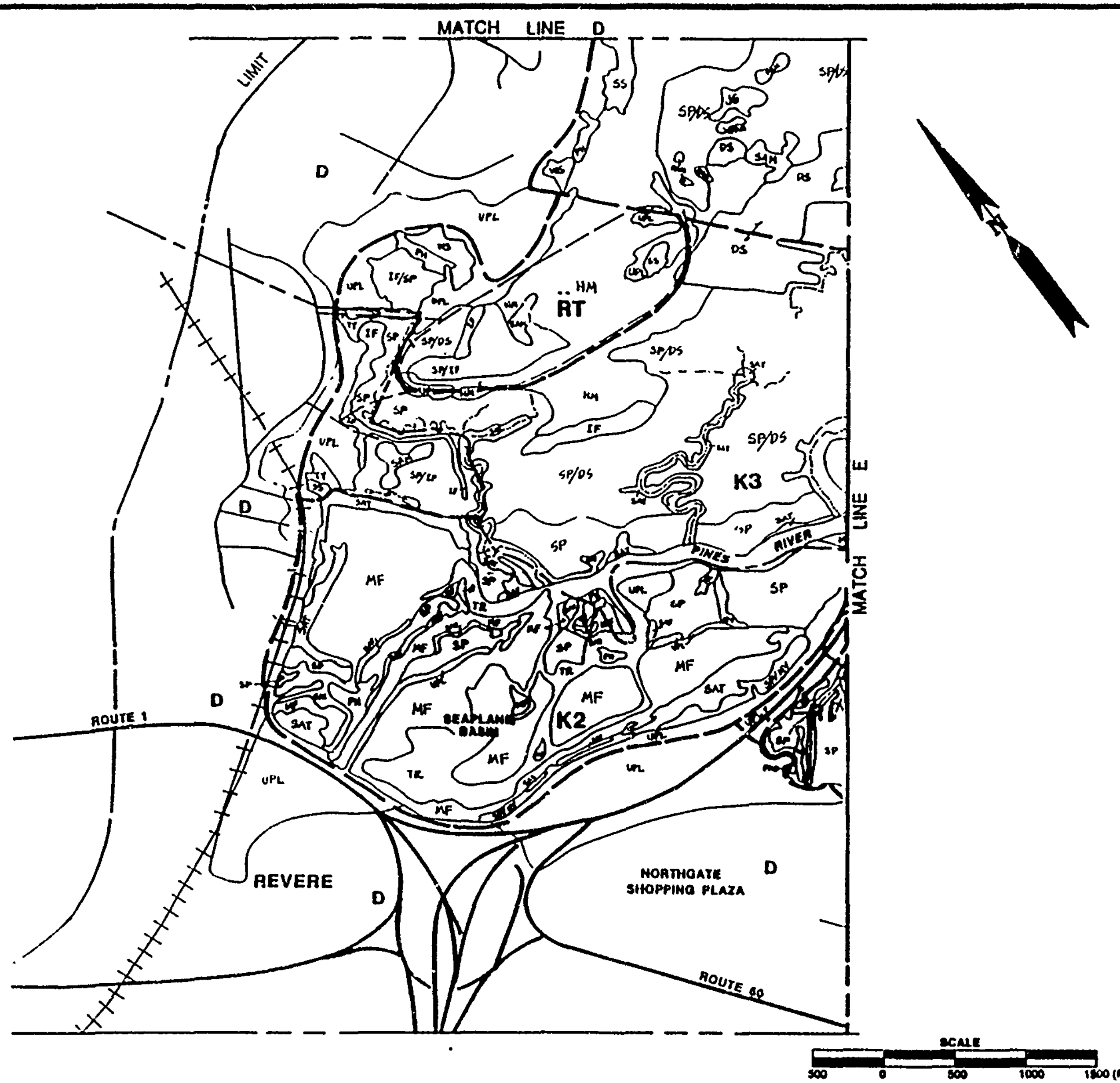
PLATE 3 :

WETLAND COVER TYPES WITHIN PROJECT AREA COMPARTMENTS



SAUGUS RIVER & TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

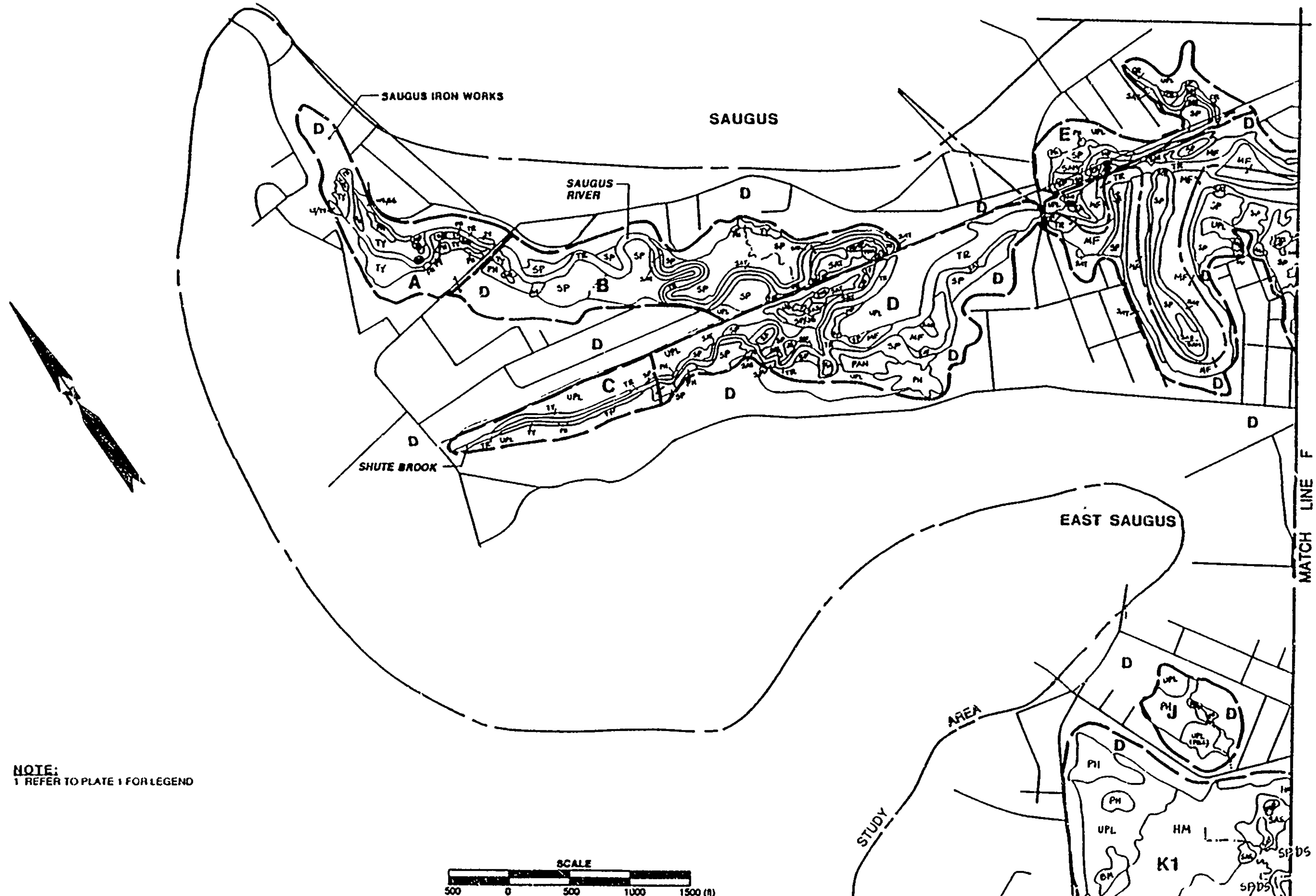
PLATE 4:
WETLAND COVER TYPES WITHIN PROJECT AREA COMPARTMENTS



SAUGUS RIVER & TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

PLATE 5: WETLAND COVER TYPES WITHIN PROJECT AREA COMPARTMENTS

NOTE:
1 REFER TO PLATE 1 FOR LEGEND



NOTE:
1 REFER TO PLATE 1 FOR LEGEND

SAUGUS RIVER & TRIBUTARIES
FLOOD DAMAGE REDUCTION STUDY

PLATE 6:
WETLAND COVER TYPES WITHIN PROJECT AREA COMPARTMENTS

Table K7. Wetland Community Types Delineated Within the Study Area

SUBTIDAL HABITATS
- TR: Tidal River
- PND: Pond (in part)

IRREGULARLY EXPOSED HABITATS
- MF: Intertidal Flat (in part)
- CR: Creek
- PND: Pond (in part)

REGULARLY FLOODED HABITATS
- SAT: Spartina alterniflora, tall form (>0.8m), dominates
- MF: Intertidal Flat (in part)

IRREGULARLY FLOODED HABITATS
- HM: High Marsh, undifferentiated
- SP: Spartina patens dominates
- SP/DS: Spartina patens, Distichlis spicata, near equal dominance
- DS: Distichlis spicata dominates
- JG: Juncus gerardii dominates
- SAS: Spartina alterniflora, short form (<0.3m), dominates
- SAM: Spartina alterniflora, mid-height (0.3m-0.8m), dominates
- IF: Iva frutescens dominates
- TY: Typha spp. dominates
- PH: Phragmites australis dominates
- LY: Lythrum salicaria dominates
- BM: Brackish Marsh (mixed composition)
- PAN: Panne
- NV: Non-vegetated

SEASONALLY FLOODED FRESHWATER HABITATS
- SS: Shrub Swamp
- WS: Wooded Swamp

UPL Upland

Possible exceptions to the estuarine classifications are the very upper reaches of the Saugus River and Shute Brook within the Study Area; in-channel salinity readings during late summer low tides (<0.5 ppt) indicate these reaches to be more appropriately classified as riverine permanently flooded-tidal zones, although the adjacent marshes having higher interstitial salinities are primarily considered to be estuarine.

Within the regularly flooded and irregularly flooded zones, the dominant vegetative species have been delineated on the cover maps to the extent possible. In places, particularly in the irregularly flooded marsh, species interspersion is so varied that no single dominance type can be delineated at this scale. When these undifferentiated types cover large areas they have been classified as undifferentiated high salt marsh; otherwise they have been incorporated into the surrounding cover type. Brief descriptions of the various community types delineated on the cover maps of the Study Area and listed in Table K7 are provided below:

Subtidal Habitats

Subtidal zones, or areas where the substrate is permanently flooded with tidal water, have been labeled primarily as "TR" (for tidal river). These include the Saugus and Pines Rivers proper, Diamond Creek, Shute Brook and major tributary channels to these waterways. An attempt has been made to differentiate these from smaller creeks which may periodically become exposed during extreme low spring tides. Permanently flooded ponds ("PND") are also included within this water regime, although they are often situated in intertidal marshes. The submergent widgeon grass (Ruppia maritima) was frequently observed in such ponds.

Irregularly Exposed Habitats

These are areas where the land is exposed by tides less often than daily, and includes the tidal creeks ("CR"), some ponds ("PND") within the salt marshes which are drawn-down, and portions of the intertidal flats ("MF"). The extensive linear man-created ditches which often cut through the high marsh areas were not usually considered as creeks and were not mapped. The intertidal flats, or unconsolidated shores, appear to be composed principally of silt and clay-sized mineral sediments with organic detrital matter; both algal communities (e.g., in the Sea Plane Basin) and benthic faunal communities were observed. The USGS topographic maps were frequently used to supplement the delineation of tidal flats, since they designate such areas; for the most part, however, the delineations were based upon different tonal patterns on the photographs which appeared to differentiate deepwater areas from irregularly exposed habitat.

Regularly Flooded Habitats

Areas delineated within this zone are exclusively dominated by saltmarsh cordgrass (Spartina alterniflora), and comprise the traditional "low salt marsh" of the northeast coast. These areas are delineated as "SAT" on the cover maps, distinguishing the tall form of S. alterniflora (>0.8m) from less-frequently flooded shorter forms (Reinert et al., 1981; Teal, 1986).

Associated species which may occur within this zone include glassworts (Salicornia spp.), sea lavender (Limonium nashii) and spike grass (Distichlis spicata). Often, this delineated cover type includes small creeks within it.

Irregularly Flooded Habitats

These habitats are typically at or slightly above the elevation of mean high tide, such that tidal water floods the land less often than daily. This zone encompasses the traditional "high salt marsh" most often dominated by saltmeadow grass. Much of this community type within the Study Area has been extensively ditched in the past.

Within the irregularly flooded high salt marsh portions of the Study Area, the following cover or dominance types have been delineated:

- HM: These are areas of high salt marsh within which species interspersion was so varied that individual dominance types could not be delineated. These areas have therefore been grouped into an undifferentiated (by species) high marsh cover type. Typical species composition includes Spartina patens, Distichlis spicata, black rush (Juncus gerardii) and short (<0.3m) Spartina alterniflora). Less abundant but common associates include arrowgrass (Triglochin maritima), sea lavender (Limonium nashii), marsh elder (Iva frutescens) and glasswort (Salicornia europea). This cover type was most extensive in Compartment M1 and in the vicinity of the old Saugus Race Track, west of the abandoned I-95 road bed and north of the Seaplane Basin (Compartments K1, K3 and RT).

- SP: These are areas of the high marsh where Spartina patens clearly comprises a major proportion of the vegetative cover, such that it is considered to dominate the area. Most common associates in this cover type are Distichlis spicata and the short form of Spartina alterniflora.

- SP/DS These are areas of the high marsh where Spartina patens and Distichlis spacata are nearly equally dominant. Through most of these areas the two dominant species grow in mixtures rather than monotypic stands. Common associates in this cover unit include Juncus gerardii, Spartina alterniflora and Triglochin maritima.

- DS: Distichlis spicata, or spike grass, visibly comprises a major proportion of the cover of areas designated as "DS". Within the Study Area such zones appeared to occur in areas of the high marsh which are slightly lower in elevation than areas dominated by Spartina patens, or where surface drainage was slightly impeded. The most extensive stands of this dominance type occurred just east of the old Saugus Race Track and appeared associated with past disturbance by man.

- JG: Juncus gerardii, black rush, was occasionally delineated as a dominance type.

. SAS: These are portions of the irregularly flooded salt marsh where the short form of *Spartina alterniflora* is dominant. For the purposes of this report, areas where the cordgrass is predominantly less than 0.3m tall are grouped in this category (Reinert et al., 1981; Teal, 1986). Such areas are typically associated with slightly lower elevations than the *Spartina patens* dominance type, and where surface drainage is impeded. This community type has been associated with higher interstitial salinities and more reduced soil conditions than regularly flooded zones of *Spartina alterniflora* (Teal, 1986; Niering and Warren, 1980; Nixon, 1982).

. SAM: Areas where the *Spartina alterniflora* appeared to reach late-summer heights of 0.3m to 0.8m tall were differentiated as mid-height zones of saltmarsh cordgrass.

. IF: *Iva frutescens*, marsh elder or high-tide bush, was occasionally delineated as a dominance type where it comprised stands extensive enough to map at the scale being used. This is a woody or semi-woody shrub, normally 1.0-1.5m tall, most often found at the highest elevations of the salt marsh edges or on spoil mounds along mosquito ditches. A thin band of *Iva* is typical at the edge of many of the marshes, but often was too narrow to delineate for this study.

. PAN: These are areas termed pannes, which are localized depressions in the high marsh which typically are sparsely vegetated with only a few species, and usually have shallow standing water which rarely draws down completely. Short *Spartina alterniflora* and glasswort (*Salicornia europea*) are the most common plant species found within these areas, although algal growth may also be extensive. These are distinguished from the following cover type, non-vegetated (NV), by the perception that pannes are formed largely by natural processes (Miller and Egler, 1950; Redfield, 1972).

. NV: Several non-vegetated areas were delineated within the Study Area high marshes which did not fit the classic definition of panne and appeared to have resulted from relatively recent activities of man.

In addition to the true salt marsh habitats of the irregularly flooded zone, a number of units were delineated which are comprised of non-halophytes yet which are subject to tidal inundation on an irregular basis and where salinity data indicated the influence of ocean-derived salts. Several such areas were comprised of a mixed assemblage of plant species with no apparent dominant species, and were therefore classified as brackish marsh ("BM"). Areas dominated by common reed (*Phragmites australis*) were designated as "PH". Cattail (*Typha* spp.) stands in the Study Area were typically found to consist of integrated assemblages of narrow-leaved cattail (*Typha angustifolia*),

broad-leaved cattail (Typha latifolia) and the hybrid blue cattail (Typha glauca), and could not be differentiated within the scale of this mapping. Such areas are therefore labeled generically as "TY". A few areas in the upper estuarine irregularly flooded zone were dominated by purple loosestrife (Lythrum salicaria), and are labeled "LY".

Seasonally Flooded Freshwater Habitats

Occasionally bordering the wetlands which are irregularly flooded by tidal waters are freshwater wetland habitats dominated by woody vegetation. These areas are classified as shrub swamp ("SS") where the vegetation is less than 20 feet tall, or wooded swamp ("WS") where it is taller than 20 feet.

Cover Type Composition of Wetland Compartments

Table K8 presents the acreages of the various community cover types for the 24 Study Area wetland compartments. Of the 1656.72 acres of wetland and deepwater habitat mapped within the Study Area, nearly one-third (30.8%) consists of high salt marsh dominated by Spartina patens, with other high salt marsh cover types comprising an additional 17.7% of the area. Non-salt marsh vegetative cover within the irregularly flooded zone is predominantly Phragmites australis, which covers 8.5% of the Study Area wetland. A considerable portion (19.9%) of the wetland/deepwater habitat consists of regularly flooded and irregularly exposed tidal flats, frequently bordered by Spartina alterniflora low marsh (7.0%). Tidal river habitat covers 14.3% of the 1,656.72 acres.

The cover type composition of each of the 24 wetland compartments is briefly described below.

Compartment A (9.5 acres): Situated in the northwest corner of the Study Area (Figure K7), Compartment A encompasses the brackish zone of the upper Saugus River below the Saugus Iron Works and above the Woodbury Avenue crossing. The limit of tidal influence on the Saugus River occurs at the upper boundary of this compartment at the Iron Works. The mixed influence of fresh and salt water is reflected in salinity data and plant species composition. The largest portion of Compartment A (52%) is dominated by cattails (Typha spp.). The Saugus River itself comprises 21% of this compartment. Stands of Phragmites are found at various scattered locations and encompass about 10% of the wetland area. Salinity gradients throughout the compartment are further reflected in the presence of fresh-to-brackish vegetative gradients of purple loosestrife (Lythrum salicaria) marsh near the Iron Works, to a bank of Spartina alterniflora along the River near the culvert at Woodbury Avenue which progressively thins out moving upstream.

Compartment B (31.0 acres): Situated just southeast of Compartment A, wetland conditions within Compartment B change abruptly to true salt marsh. Over one-half (57%) of the area is high marsh dominated by Spartina patens which has been heavily ditched in the past; ditches occur roughly every 50 feet through most of the high marsh area. Although freshwater influences are indicated by vegetative composition near Woodbury Avenue and along the wetland

Table K8. Acreages of Cover Types by Wetland Compartment.

Wetland Compartment	COVER TYPE: SUB-TIDAL		IRREG. EXPOSED	REG. FLOODED		IRREGULARLY FLOODED													SEASONALLY FLOODED		UPLAND	Total Acreage
	TR	PND	CR	MF	SAT	HM	SP&SP/DS	DS	JG	SAM	SAS	PAN	IF	NV	BM	PH	TY	LY	SS	WS	UPL	
A	1.99			.26	.43											.97	4.90	.27	.24	.40		9.46
B	6.06		*	.18	4.85		17.76	1.00				.23	.09				.84					31.01
C	1.04															.03	1.67					2.74
D	8.81			2.26	4.94		9.69		1.29		.25	1.45	.16	.20		2.25						31.30
E			1.66	.49	2.20		2.55			.43						.29						7.62
F	20.65		*	58.01	12.19		13.21			1.05	.18	.19		.06								105.54
G			*													18.50						18.50
H			*													20.00						20.00
I	17.23	.07	*	45.44	16.59		44.01	.44		7.06		1.07				5.01						136.92
J		.34														3.36						3.70
K1		.10	*		7.74	54.66	20.10	9.18	1.38	3.43		2.90			1.04	6.03			3.25	.75	.80	111.36
K2	27.68			57.98	20.45		25.60							1.88		2.68					1.26	137.63
K3			*		12.88	13.53	108.77	7.16		.83	.37	.56	10.59			1.01	1.20		.85	2.05	.38	160.18
L1	2.94		*	2.22	2.41		29.87				1.00	.35				7.97						46.76
L2	4.40	.38	*	13.23	1.86		57.33			4.16	1.43					1.20						83.99
M1	39.05		*	44.37	20.00	90.26	116.02			1.00	25.95	1.43	.69	.44		9.10						348.31
M2	13.56		*	9.68	1.58		20.23									9.59						54.64
N1				1.41	.61		27.53			5.31		5.93										40.79
N2	93.09			86.42	3.68		5.57			.51	3.19											192.46
N3			*	8.16	2.16	3.00	1.81				1.00	1.00										17.13
O		1.82	*				4.92								.99	7.56			.51			15.80
P					.90											27.36						28.26
Q			*													18.00						18.00
RT						19.11	5.45	1.02		.79			3.54						.61		4.10	34.62
Totals	236.50	2.71	1.66	330.11	115.47	180.56	510.42	18.80	2.67	25.57	33.37	14.11	15.07	2.58	2.03	140.91	4.61	.27	5.46	3.20	6.64	1656.72
% of Total	14.3	0.2	0.1	19.9	7.0	10.9	30.8	1.1	0.2	1.5	2.0	0.9	0.9	0.2	0.1	8.5	0.5	0.02	0.3	0.2	0.4	

* Creeks present but were not planimetered.

Note: Upland was planimetered only when surrounded by non-upland habitat.

edges, which includes areas dominated by salt marsh bullrush (Scirpus robustus), the more extensive growth of Spartina alterniflora (16% of the area) along the Saugus River and near the compartment's terminus at the B & M railroad tracks demonstrates the greater influence of ocean-derived salts. The River itself comprises nearly 20% of the compartment as it meanders through the marsh (Table K8).

Compartment C (2.7 acres): This area is associated with the limit of the tidally-influenced portion of Shute Brook. Extending from the Central Street crossing to the point where salt marsh vegetation dominates the bordering wetland community, Compartment C is a linear stretch of Shute Brook (38% of the area) largely bordered by cattail stands (61% cover) with occasional patches of Phragmites.

Compartment D (31.3 acres): The confluence of the Saugus River and Shute Brook occurs within this compartment which extends from Compartment B and C to the culvert at Lincoln Avenue. The rivers themselves comprise over 28% of Compartment D, with substantial stands of Spartina alterniflora (16%) and more than 2 acres (7.3%) of tidal flat bordering the rivers. High marsh covers 36% of the area, largely dominated by Spartina patens but with common occurrence of black rush (Juncus gerardii).

Compartment E (7.6 acres): This is an area of salt marsh physically separated from the Saugus River by the B & M railroad bed but hydrologically connected through culverts. Spartina patens and S. alterniflora each cover roughly one-third of the area of Compartment E, with most of the remaining area consisting of a relatively large creek. Phragmites stands are present in scattered localized areas.

Compartment F (105.5 acres): This area comprises the Saugus River and its wetlands between Lincoln Avenue and Route 107. Compartment F contains an extensive area of tidal flats, covering more than one-half (55%) of the 105 acres. A portion of these flats has developed within what appears to be an old ox-bow channel of the Saugus River which is now by-passed by most of the flow. The Saugus River itself comprises nearly 20% of Compartment F. The relatively small amount of vegetated wetland in this compartment consists of Spartina patens dominated high marsh (13%) bordering a nearly equal amount of S. alterniflora low marsh.

Compartment G (18.5 acres): This area is located south of Compartment F along the west side of the abandoned I-95 roadbed. Compartment G consists of a nearly monotypic stand of Phragmites with woody growth present in localized patches. This area, historically, was salt marsh.

Compartment H (20.0 acres): Situated across the I-95 roadbed from Compartment G, Compartment H is similar in composition. The two areas are hydrologically connected via an excavated channel. Prior to construction of the now abandoned I-95 embankment this area was salt marsh.

Compartment I (136.9 acres): This area encompasses the stretch of the Saugus River (12.6% of the area) extending from Rt. 107 on the west to the Boston and Maine Rapid Transit Line on the east, and extends south to the

former Saugus landfill. The western portion of Compartment I is physically separated from the larger eastern portion by what is presently the RESCO facility. A culvert under the facility may provide a hydrologic connection between these two portions of wetland, but this area was not accessible for field verification. An extensive intertidal flat system extends from the Saugus River through Compartment I and covers roughly one-third of the area. Vegetated portions of the compartment are predominantly Spartina patens high salt marsh (32%), although considerable areas of the high marsh are pocketed with pannes surrounded by varying heights of Spartina alterniflora growth.

Compartment J (3.7 acres): Situated west of the abandoned I-95 roadbed and south of Bristow Street, this relatively small area consists of Phragmites australis growth surrounding a small pond area. The area drains via a ditch to the south to Compartment K1.

Compartment K1 and K3 (271.5 acres): These two portions of compartment K are contiguous and were separated only for the purpose of defining areas for study tasks. They are bounded on the east by the abandoned I-95 embankment and on the northwest by the uplands of the East Saugus and Cliftondale neighborhoods. The Sea Plane Basin (Compartment K2) and abandoned Saugus Race Track (Compartment RT) are considered separately. Approximately 86% of this area consists of vegetated high salt marsh of varying species composition. Twenty-five percent of the area contains such varied interspersion of species that it was not possible within the scale used to delineate cover according to dominance type; these areas, classified as undifferentiated high marsh (HM), are located along the northwesternmost portion of the marsh in this area. The species composition in this area of undifferentiated high marsh appears to reflect a somewhat disturbed condition, which may have resulted from anthropogenic alteration of the area. This compartment also contains areas dominated by Spartina patens and Spartina patens/Distichlis spicata. These cover types are located to the east of the HM cover type. An unusual zone of high marsh is present in the northern part of K3 extending into the center of RT. The marsh in this area consists of linear bands of slightly depressed marsh, composed almost exclusively of spike grass (Distichlis spicata) and extending east-west from the old Saugus Race Track toward the abandoned I-95 roadbed. Spartina alterniflora low marsh is largely confined to areas bordering creeks which extend into the compartments from a channel which is located alongside the abandoned roadbed and along four creeks which penetrate into the marsh from the Pines River; combined, they comprise roughly 8% of the compartment. Phragmites australis cover (3%) has taken hold on the disturbed erosional border along the roadbed, and is also present in localized stands in the northwest border of the compartment.

Compartment K2 (137.6 acres): Compartment K2 is largely comprised of the Sea Plane Basin and its associated ti. ' flats. Town Line and Linden Brooks converge within K2 to form the Pines River; deepwater habitat associated with the River encompasses 20% of the compartment. The intertidal flats comprise most of K2, covering over 42% of the area. Portions of these flats have heavy algal growth over the sediments. Regularly flooded tall Spartina alterniflora commonly borders the flats, and covers nearly 16% of the area.

High marsh communities cover roughly 20% of K2. Several stands of Phragmites australis are distributed widely through the compartment; combined, they cover 2% of the area.

Compartment L1 (46.8 acres): L1 is a long, linear stretch of salt marsh situated alongside of the Pines River and between the abandoned I-95 roadbed and Route 107. The compartment is principally (68%) high salt marsh dominated by Spartina patens. Phragmites covers 17% of the area, primarily along the border of the I-95 roadbed. Tidal river, mud flat and low marsh each comprise roughly 5% of Compartment L1.

Compartment L2 (84.0 acres): Situated between the Pines River and Route 107, L2 is also primarily high salt marsh (76%) dominated by Spartina patens (68% of the compartment). The northern portion of L2 consists of tidal river and contiguous mud flats (combined cover of 21% of L2) associated with the Pines River and Diamond Creek which converge within this compartment. Scattered stands of Spartina alterniflora comprise the majority of the remaining area (8.9% of L2). Phragmites again occurs along the erosional edge of the fill from the abandoned I-95 roadbed.

Compartment M1 (348.3 acres): M1 encompasses the salt marsh south of the Pines River between Route 107 and the B & M Rapid Transit Line. As with most of the Study Area, Spartina patens high marsh is the most extensive cover type, comprising 33% of M1. Other cover units of the irregularly flooded zone encompass roughly 39% of the area. Most notable are some fairly large areas of short Spartina alterniflora often associated with pannes. A fairly distinctive feature of the M1 high marsh is the relatively common occurrence of seashore alkali grass (Puccinellia maritima). A band of Phragmites australis fringes the high marsh along the south and east edges, and covers over 3% of the total area of M1.

Diamond Creek meanders through the southern portion of M1 toward its confluence with the Pines River, and together the two rivers comprise roughly 12% of the compartment. Tidal flats associated primarily with the Pines River cover nearly an additional 13% of M1. Fringing low salt marsh dominated by tall Spartina alterniflora covers 20 acres or 5.7% of the compartment.

Compartment M2 (54.6 acres): M2 is bounded on the north and west by the former Saugus landfill, on the south by the Pines River, and on the east by the B & M Transit Line. The compartment is comprised principally (37%) of Spartina patens high salt marsh, with lesser amounts of deepwater habitat associated with the Pines River (25%) and adjacent tidal flats (18%). Small stands of Spartina alterniflora occasionally border the flats. Phragmites australis growth borders the salt marsh along the landfill and covers nearly 18% of the compartment.

Compartment N1 (40.8 acres): Situated along the east side of the Boston and Maine Rapid Transit Line and west of the Pines River and its contiguous tidal flats, N1 is predominantly (67%) Spartina patens high salt marsh. The northern portion contains a large number of pannes interspersed among varying heights of Spartina alterniflora, with each community type covering roughly 14% of the compartment.

Compartment N2 (192.5 acres): Compartment N2 encompasses the lower stretch of the Pines River below the B & M Rapid Transit Line to its confluence with the Saugus River, and includes the Saugus River between the Transit Line and the General Edwards Bridge. Nearly one-half (48.4%) of the compartment is deepwater tidal river habitat associated with the two rivers, while 45% consists of the tidal flats which border the rivers. Only small amounts (approximately 7%) of the compartment consist of vegetated salt marsh, most of which was classified as Spartina alterniflora and Spartina patens.

Compartment N3 (17.1 acres): Situated along the north shore of the Saugus River just upstream of the General Edwards Bridge, Compartment N3 is predominantly (48%) tidal flat within the irregularly exposed zone. Bordering the flats is a salt marsh community which consists of a fringe of Spartina alterniflora low marsh along an irregularly flooded high marsh containing a relatively large proportion of pannes surrounded by short Spartina alterniflora.

Compartment O (15.8 acres): Compartment O is located between Revere Beach Boulevard and Route 1A north of Island Street. The wetland consists largely (49%) of Phragmites australis marsh and ponds in the southern portion. An undifferentiated brackish marsh also occurs in this portion containing a mixed assemblage of salt marsh and brackish marsh plant species. A small (0.5 acre) area dominated by wetland shrubs is present adjacent to Route 1A. The northern portion of the compartment is dominated by Spartina patens.

Compartment P (28.3 acres): Situated between Route 1A and the Boston and Maine Rapid Transit Line just south of Oak Island, Compartment P is almost entirely (97%) dominated by Phragmites australis. The one exception is along the border of Diamond Creek where Spartina alterniflora occurs in the regularly flooded zone.

Compartment Q (18.0 acres): This wetland is located at the extreme southern point of the Study Area, just north of Wonderland Raceway. It consists of dense Phragmites australis growth with several excavated ditches which appear to be linked via culverts to Compartment M1.

Compartment RT (34.6 acres): This compartment encompasses the remains of the former Saugus Race Track north of the Sea Plane Basin in the southwest portion of the Study Area. It has been differentiated from the adjacent K1 and K3 compartments due to the separation caused by the Race Track. Only one narrow channel was observed to link the Race Track wetland with adjacent wetland areas; this is located in the southwest corner of the Race Track. Much of the compartment (55%) has been classified here as undifferentiated high salt marsh due to the varied interpersion between Spartina patens, Distichlis spicata, Juncus gerardii and short Spartina alterniflora. Portions dominated by Spartina alterniflora were distinguished as separate cover units and comprise the remaining salt marsh of Compartment RT. Upland wooded areas occur at the eastern end of the old Race Track, where trembling aspen (Populus tremuloides) is dominant.

H. Wetlands

General

There are approximately 1,070 acres of vegetated wetland within the approximately 1660 acre Saugus and Pines Rivers Estuary (including Shute Brook). This vegetated wetland is predominantly made up of irregularly flooded (flooded less often than daily) high salt marsh (803 acres) which is typical of salt marshes of the Northeast. Regularly flooded (flooded twice a day) low salt marsh makes up 115 acres of the total, occurring mostly along the borders of the saline rivers and creeks which bring water to the marsh. Areas at the inland extremes of the marsh are dominated by brackish and fresh water emergent vegetation such as cattails (*Typha* spp.) and common reed (*Phragmites australis*). They make up 152 acres of the total vegetated wetland. A majority of the areas dominated by common reed are located in pockets of what was once salt marsh. The construction of roads and the I-95 roadbed severely restricted tidal flow to these areas creating conditions suitable for the growth of the less desirable common reed. Seasonally flooded wooded and shrub swamp are present, mostly in Compartment K, in areas transitional between marsh and upland.

Wetlands are generally credited with having functions and values which vary with the wetland type, size and location. Some of the major values ascribed to wetlands to a greater or lesser degree are outlined by Tiner (1984). These include: wildlife habitat, fish and shellfish habitat, water quality maintenance, aquatic productivity enhancement, flood and erosion control, recreational and educational opportunities, aesthetic qualities and production of consumable products. The Saugus and Pines Rivers wetlands provide all of the above values.

Historical Conditions

The wetlands of the Saugus and Pines Rivers Estuary have been subjected to intense residential and commercial development and public works projects since at least 1807. The Salem Turnpike (Route 107), completed in 1807, was the first of three barriers to tidal flushing constructed in the Saugus Marsh. It was followed in 1838 by the Boston and Maine Railroad Line and in 1968 by the embankment roadbed for the now abandoned Interstate 95 extension. The first two projects created constrictions to tidal flow in both the Pines and Saugus Rivers; the I-95 embankment placed an additional constriction in only the Pines River. All three of these projects resulted in a barrier to sheet flow over the marsh, which means that tidal water must flow through each succeeding constriction before it can spread across the marsh providing the necessary tidal inundation.

The 1946 USGS map for the area shows that North Shore Road (Route 1A) had been constructed by that time. It required the installation of the General Edwards Bridge to connect Point of Pines to Lynn. The construction of this road likely resulted in filling along the Revere Beach backshore and facilitated the construction of the Mills Avenue and Oak Island neighborhoods.

An 1884 map of the area shows that wetland was present along approximately 3500 feet of what is presently the Lynn Harbor bulkhead, extending 2000-3000 feet inland, and along the entrance to the Saugus River, northwest to the point where the WLYN radio tower is located (G.H. Walker and Company, 1884). This area presently supports commercial and industrial land uses. Bristow Street, Ballard Street and the neighborhood in the vicinity of the Saugus General Hospital had been constructed at this time, most likely at least partially on wetland.

The 1946 USGS map for the area shows that the side streets and neighborhoods surrounding Bristow Street and Ballard Street had been constructed by this time. This included the isolation of the area designated as compartment J for this study. The Saugus Race Track had been partially constructed by this time but the Revere Airport and Sea Plane Basin were absent. The smaller ponded area north of the Sea Plane Basin was, however, present. By 1946 the Lynn Harbor and Saugus River shorelines up to the WLYN radio tower had been filled to their current limits eliminating roughly 250 acres of wetlands.

By 1956, when the USGS map was updated, the Revere Airport and Sea Plane Basin had been constructed resulting in the alteration of roughly 180 acres of wetland. The Sea Plane Basin does not appear to have been connected to the Pines River at this time. Roadwork for the Saugus Racetrack was completed and approximately 30 acres of fill had been deposited in the wetland abutting the Salem Turnpike to the north and the Pines River to the south where the Saugus Landfill is presently located.

By the time the USGS maps were updated in 1970 and 1971, the Sea Plane Basin was connected to the Pines River, the I-95 embankment had been installed, and roughly 100 acres were filled at the Saugus Landfill. Several acres of fill were also deposited in the vicinity of the WRYT radio tower. The Revere Airport had been removed and the Northgate Shopping Center had been constructed in its place.

The photorevision of the Boston North quadrangle in 1979 shows new development in the area just south of the Northgate Shopping Center which resulted in approximately 10 acres of wetland filling.

The most obvious wetland alteration since the last USGS map updates is the expansion of the Saugus landfill. The northernmost portion of the wetland between Route 107 and the B and M Railroad line has been divided by fill into two separate portions by a utility road. The southernmost portion of wetland in this area has been decreased in size by expansion of the fill southwestward. Approximately 50 acres of wetlands have been filled in this area.

The preceding chronology shows that large portions of the estuary wetlands have been altered for various forms of development. Each alteration affects the capacity of the wetland to provide the functions and values commonly associated with wetlands, most notably in this case fish and wildlife values. Without the availability of pre-development information to describe the marsh vegetation, it can be surmised that the Saugus/Pines

marshes supported vegetation typical of undisturbed marshes of the area and the host of fish and wildlife typically associated with these areas. At the very least, the historic encroachment on the marsh has reduced its carrying capacity for fish and wildlife and its ability to perform other functions commensurate with the area lost.

Existing Conditions

Salt Marsh

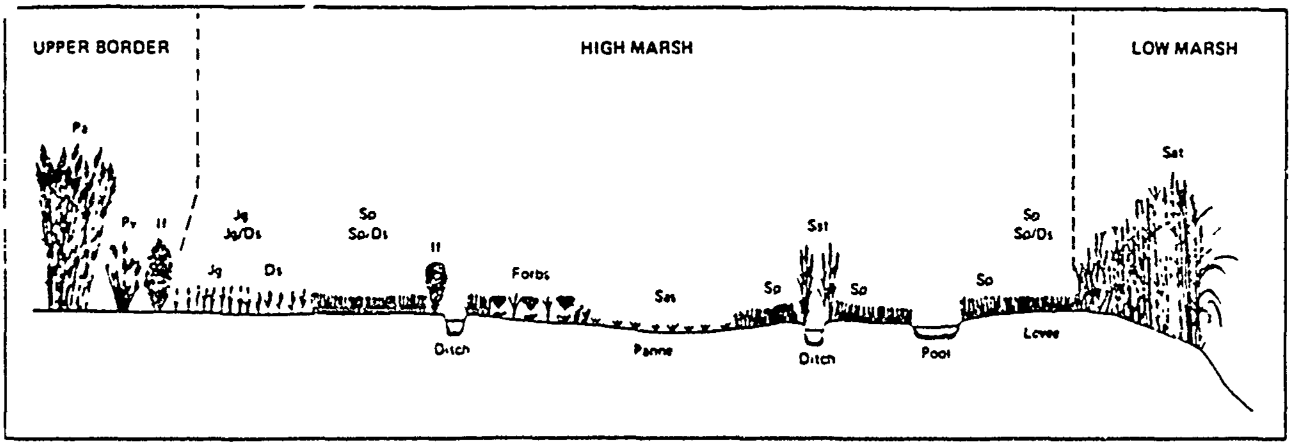
Introduction

Salt marshes are divided into two types based on the frequency of tidal flooding: low marsh and high marsh. Low marsh or regularly flooded salt marsh extends to roughly the level of mean high water (MHW) and is therefore flooded twice each day in New England. High marsh extends from the inland limit of low marsh to the level of the highest lunar tides (Lefor, 1987). Salt marsh of the Saugus/Pines wetland is predominantly high marsh.

High marsh vegetation in New England is typically dominated by saltmeadow grass (*Spartina patens*) as it is in the Study Area high marsh. Nixon (1982) described the upland to bay open water vegetation sequence developed by Miller and Egler (1950) as "probably the most useful general model of vegetation on the New England salt marshes...their general upland-to-bay sequence consisted of a *Panicum virgatum* upper border, a *Juncus gerardii* upper slope, a *Spartina patens* lower slope, and a *Spartina alterniflora* lower border."

The above is a very simplified marsh profile. Salt marshes typically support a number of other species of vegetation, most notably spike grass (Distichlis spicata) which often makes up a large portion of the high marsh vegetation as it does west of the I-95 embankment in the Study Area. A more detailed generalized marsh profile was prepared by Niering and Warren (1980) and is shown in Figure K8. The Study Area salt marsh is more reflective of this varied profile which shows that the gradation from open water to upland is often interrupted by mosquito ditches, pannes, pools and mounds or levees. Marsh elder (*Iva frutescens*) is often present along the upland border between the switchgrass (*Panicum virgatum*) and blackgrass (*Juncus gerardii*) zones and on levees along mosquito ditches. A number of forbs such as sea lavender (*Limonium carolinianum*) and seaside goldenrod (*Solidago sempervirens*) are also present on the high marsh, often associated with bare patches (Bertnes and Ellison, 1987). Areas of restricted drainage often support the short form of saltmarsh cordgrass (*Spartina alterniflora*) and slender glasswort (*Salicornia europea*). This pattern of vegetation on the high salt marsh is dependent on a number of changeable physical and biotic factors, and plant species composition may change significantly over a period of time (Nixon, 1982).

The low marsh supports a much smaller variety of plants, almost always dominated by saltmarsh cordgrass (*Spartina alterniflora*). Some of the high marsh forbs and glassworts may be found on the low marsh but their abundance is very limited.



Generalized vegetation bisect from intertidal zone to upland showing major vegetation types that may be encountered on southern New England marshes. Key to symbols. Sat = *Spartina alterniflora*, tall, Sp = *Spartina patens*, Ds = *Distichlis spicata*, Sas = *S. alterniflora*, short; If = *Iva frutescens*; Jg = *Juncus gerardi*; Pv = *Panicum virgatum*; Pa = *Phragmites australis*.

(From Niering and Warren, 1980).

Figure K8

Methodology

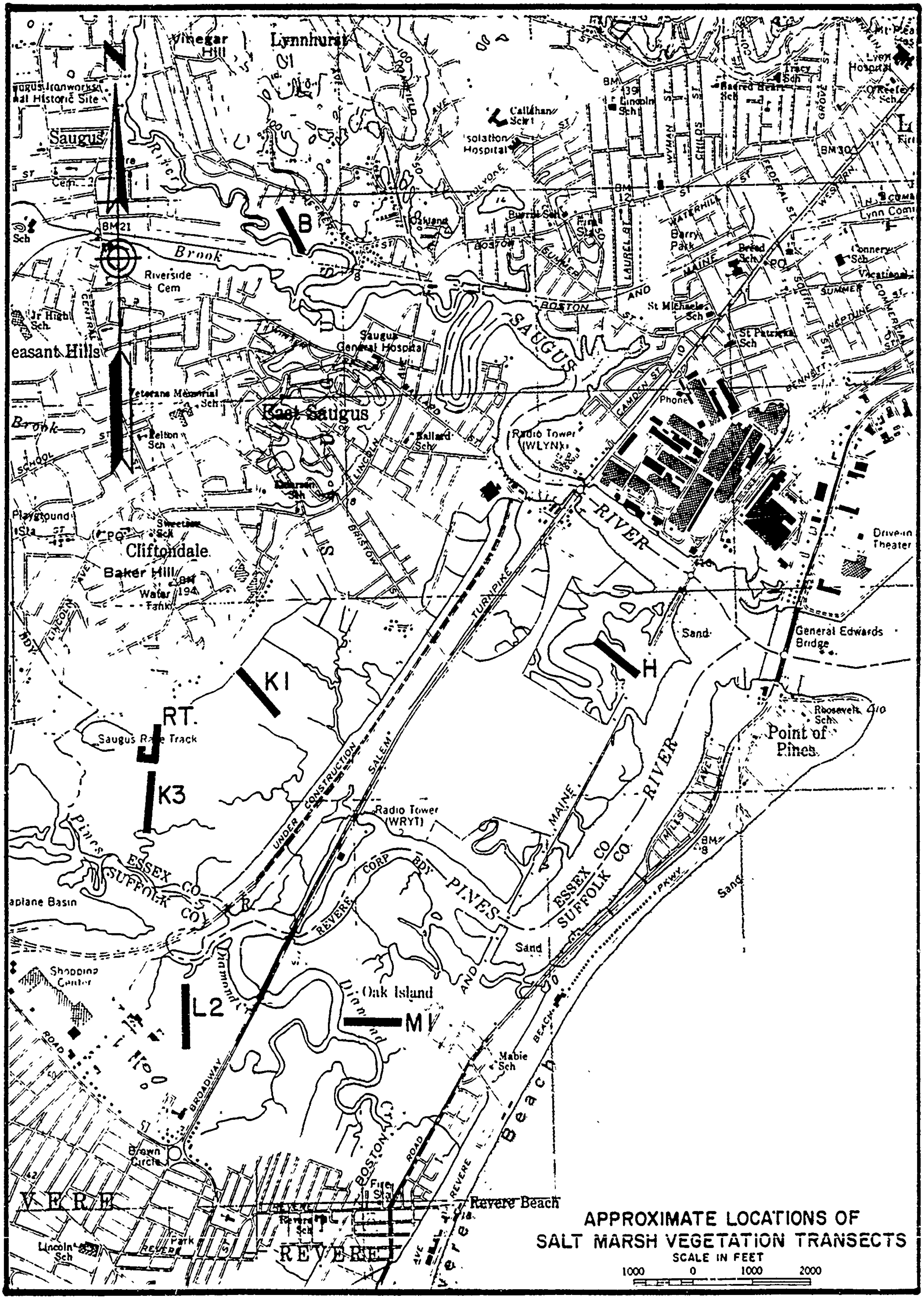
In order to characterize the vegetation of the Saugus/Pines salt marsh in greater detail seven representative transects were established in various portions of the salt marsh (Compartments B, I, K1, K3, L2, M1 and RT) (Figure K9). The transect locations were chosen so that physically similar compartments of salt marsh which were not sampled could be compared to those that were sampled. Compartment B was sampled; Compartments D, E and F are expected to be similar to Compartment B and somewhat transitional between Compartments B and I. Compartment I was sampled because it is the only large area of salt marsh on the Saugus River and it is similar in size to M2. Compartments M1 and M2 were considered to be similar as were L1 and L2 (M1 and L2 were sampled). Compartments K1, K3 and RT were all sampled because of the visually obvious variability of the vegetation in this area. K2 was not sampled because it is mostly open water. Compartments H, J, G, O, P and Q are small and isolated areas mostly dominated by common reed (Phragmites australis). Since these six areas are of relatively low value compared to the salt marsh areas, they were not sampled for vegetative composition. Compartments N1, N2 and N3 were not sampled because they are least likely to be affected by the project. Vegetative composition of Compartments A and C are discussed in later sections.

Transect locations were initially selected in a stratified random fashion on aerial photographs by selecting observable control features which could be located in the field as starting points, and extending the transects generally perpendicular to the salt marsh/upland edge. Transects extended 300m (984 feet) into the salt marshes or until they encountered either open water or upland; in most instances the full 300m transect was established.

Starting at the upland edge, 5m x 5m sample stations were established at 30m intervals along the transect. Within each 5m x 5m sample station, three corner $1m^2$ (2m x 0.5m) plots were established; for convenience, it was assumed that each transect was oriented toward due north; the northwest, northeast and southeast corners were identified relatively, for the corner plots. Within each 1m2 plot, all plants were identified to species (or tagged and collected for later identification, if necessary), percent cover was estimated for each species and for the entire plot, and the maximum height was measured for each species comprising greater than 5% cover. At the center of each station a soil sample from the top 10" of the soil profile was obtained using a 3-inch diameter Dutch auger. Soil samples were visually characterized by degree of decomposition of organic matter and bagged for later analysis of organic matter content and grain size.

Results

Among all transects sampled Spartina patens (86%), Distichlis spicata (67%), Atriplex patula (35%), Spartina alterniflora (30%) and Juncus gerardii (17%) were the five species with the highest percent frequency of occurrence; that is, they were present in the greatest number of $1m^2$ plots sampled (Table K9). Within areas the percent frequency of occurrence of S. patens was exceeded only 3 times, in all cases by D. spicata. This occurred



APPROXIMATE LOCATIONS OF SALT MARSH VEGETATION TRANSECTS

FIGURE K9

Table K9. **Summary of Percent Frequency of Occurrence of Species Present in the Project Area Salt Marsh** Transects

Species	Percent Frequency of Occurrence[1]
Spartina patens	86
Distichlis spicata	67
Atriplex patula	35
Spartina alterniflora	30
Juncus gerardii	17
Puccinellia maritima	14
Salicornia europea	13
Solidago sempervirens	12
Limonium nashii	9
Agrostis stolonifera	8
Iva frutescens	8
Panicum virgatum	7
Juncus balticus	6
Teucrium canadense	5
Unidentified grass	4
Triglochin maritima	4
Agropyron pungens	3
Convolvulus sepium	2
Amoracia lapathifolia	2
Spartina pectinata	2
Euthamia tenuifolia	2
Rosa sp.	1
Myrica pensylvanica	1
Spiraea latifolia	1
Suaeda maritima	1
Chenopodium album	1
Vicia cracca	1
Polygonum ramosissimum	0.5
Parthenocissus quinquefolia	0.5
Artemesia biennis	0.5
Solidago rugosa	0.4
Unidentified herb	0.4
Hierochloe odorata	0.4
Calystegia sepium	0.4

Total number of $1m^2$ plots in project area salt marshes = 207

[1]Percent frequency of occurrence = number of $1m^2$ plots in which a species occurs ÷ total number of $1m^2$ plots.

in Compartments B, K3 and RT. The values for S. patens and D. spicata were very similar (differing by only 6 points) in Compartment K1. These compartments and Compartment I were the only locations of a D. spicata map unit in the cover mapping. Each of these areas is remote from saline influence and Compartments K1, K3 and RT appear to have been subject to anthropogenic disturbance.

In all compartments sampled, except Compartment K3, S. patens was the dominant species in terms of mean percent cover. Although the results of this sampling by transect and sample station were so variable that they were not statistically significant, the dominance of S. patens is supported by the results of cover mapping. The high variability within transects and stations reflects the high degree of interspersion of the salt marsh vegetation.

The percent frequency of occurrence was calculated for each of the 34 species identified in the 207 $1m^2$ plant plots in the salt marsh transects and are presented in Table K9. Spartina patens had the highest frequency of occurrence, occurring in 86% of the sample plots. Spartina patens also had the highest mean percent cover along 6 of the 7 transects, with a range of 29-66%. The dominance of this species along the salt marsh transects is expected, as the Spartina patens cover type comprises nearly 31% of the total Study Area (Table K8). Distichlis spicata had a higher mean percent cover only along the transect through the salt marsh Compartment K3 and had a range along the 6 transects in which it occurred of 4-54%. Distichlis spicata was present in 67% of the 207 $1m^2$ plant plots. Atriplex patula and Spartina alterniflora are also relatively common throughout the salt marsh, with percent frequencies of occurrence of 35 and 30, respectively.

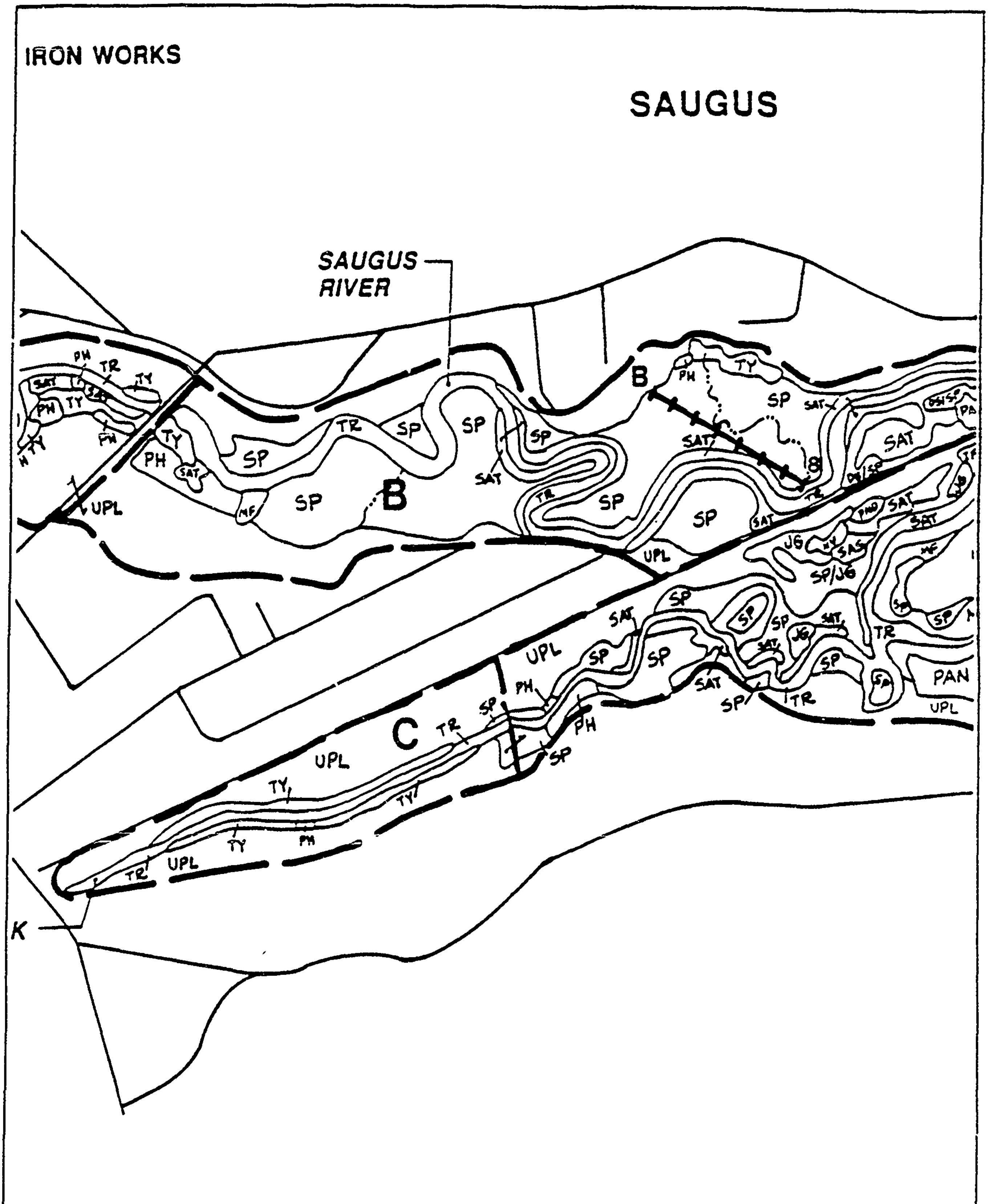
The soil analyses for the seven salt marsh transects which received detailed study are summarized in Table K10. Although all the soil samples collected were classified as highly decomposed sapric organics based on field examination, by technical definition most of the samples collected along the K1, L2 and RT transects were mineral soils. Soils in these transects generally have organic contents between 15% and 30%.

Compartment B Transect

The transect established within Compartment B traversed the marsh north of the Saugus River, starting just east of Floyd Street and Morris Place and extending roughly 215m in a southeasterly direction to the edge of the Saugus River (Figure K10). Compartment B was considered to be representative of salt marsh of the upper estuary (Compartments D, E and F). Only 8 sample stations were established on this transect because it could not extend a full 300m. The transect crossed seven man-created mosquito ditches; three of the 24 $1m^2$ plots contained ditches within their boundaries. The delineated cover type through which the transect traversed is Spartina patens - dominated high marsh, although a fringe of Spartina alterniflora low marsh occurs along the Saugus River; the latter species is also common within and on the banks of the ditches which cut through the marsh.

Table K10. **Summary of Soil Analyses for the Salt Marsh Transects**

Transect		% Moisture	% Organic Matter	% Digestible Matter	% Undigestible Matter	% Sand	% Silt	% Clay
B	mean ± S.D.	72 ± 6	28 ± 7	17 ± 4	5.8 ± 2.3	8.0 ± 6.3	30 ± 6	40 ± 6
	range	62 - 82	17 - 37	9 - 23	1.9 - 8.9	2.0 - 20.0	21 - 37	27 - 46
I	mean ± S.D.	66 ± 25	29 ± 8	---	9.1 ± 3.7	10.5 ± 3.1	31.1 ± 11.3	34.0 ± 8.9
	range	49 - 87	14 - 43	---	3.0 - 15	7.0 - 15.6	13.9 - 47.6	22.4 - 47.2
K1	mean ± S.D.	61 ± 16	16 ± 21	---	9.4 ± 9.2	49.2 ± 15.0	20.9 ± 7.8	14.0 ± 13.0
	range	30 - 79	3.9 - 61	---	0.7 - 32	21.2 - 62.9	10.8 - 33.4	4.2 - 34.8
K3	mean ± S.D.	61 ± 20	25 ± 16	---	6.8 ± 4.6	34.2 ± 23.5	25.5 ± 10.5	25.8 ± 15.2
	range	25 - 81	4.9 - 59	---	2.5 - 18	5.3 - 73.7	12.2 - 41.5	4.8 - 43.3
L2	mean ± S.D.	59 ± 14	15 ± 7	---	9.2 ± 14.1	11.9 ± 9.1	45.6 ± 14.8	34.8 ± 17.1
	range	29 - 75	3.5 - 27	---	1.3 - 46	5.7 - 35.1	12.1 - 62.7	13.8 - 59.8
M1	mean ± S.D.	76 ± 5	29 ± 9	14 ± 8	6.8 ± 4.9	15.1 ± 10.4	30 ± 7	35 ± 9
	range	70 - 86	16 - 44	1.3 - 25	2.0 - 18	3.3 - 34.0	16 - 40	24 - 50
RT	mean ± S.D.	43 ± 19	14 ± 15	10.6 ± 5.5	5.2 ± 3.1	45 ± 17	22.7 ± 10.6	16.4 ± 12.4
	range	27 - 69	5.8 - 51	6.7 - 25	1.3 - 10	17 - 61	9.5 - 45	5.3 - 43



SCALE:
1" = 500'

SAUGUS / PINES RIVERS
ESTUARINE WETLANDS STUDY

COMPARTMENT B
VEGETATION
TRANSECT LOCATION

Figure K10

Spartina patens occurred within 91% of the $1m^2$ plots with a mean cover of 49% (Table K11). *Distichlis spicata* was equally abundant, forming an almost complete cover with . The next most common species, tall (120cm height) *Spartina alterniflora*, occurred in one-third of the plots with a mean cover of only 14%. As noted above, this species was encountered primarily along the ditches or bordering the Saugus River. A total of only eight plant species were observed along the transect; however, overall vegetative cover along the transect was 85%.

Soils along the transect are highly decomposed, sapric organics, with a mean organic matter content of the samples of 28% and a range of 17-37%. The mean grain sizes of the soil samples, expressed as percentages of dry weight, are 8% sand, 30% silt and 40% clay.

Compartment I Transect

Plant species composition data within Compartment I were obtained along a 300m long transect starting at the Boston and Maine Rapid Transit Line and extending west toward the large tidal flat/creek which cuts through the marsh (Figure K11). Although several ditches cut through the transect, the pockets of pannes surrounded by short to mid-height *Spartina alterniflora*, which are widespread throughout the compartment, more strongly influenced the data.

Spartina patens occurred more frequently (73% vs 67% frequency), and with greater mean cover (53% vs 35%) than *Spartina alterniflora*, and no other species appears to be a major component of the community (Table K12). Only seven species were recorded within the 30 $1m^2$ plots inventoried along the transect, although mean total vegetative cover is nearly 90%. Many of the other species observed (*Salicornia europea*, *Suaeda maritima*, *Limonium nashii*) also reflect the wetter conditions associated with the pannes.

The soils along the I transect are highly decomposed, sapric organics with organic matter content ranging from 14-43% and a mean of 29%. The mineral component of these soils, expressed as mean percentages of dry weight, is 11% sand, 31% silt and 34% clay.

Compartment K1 Transect

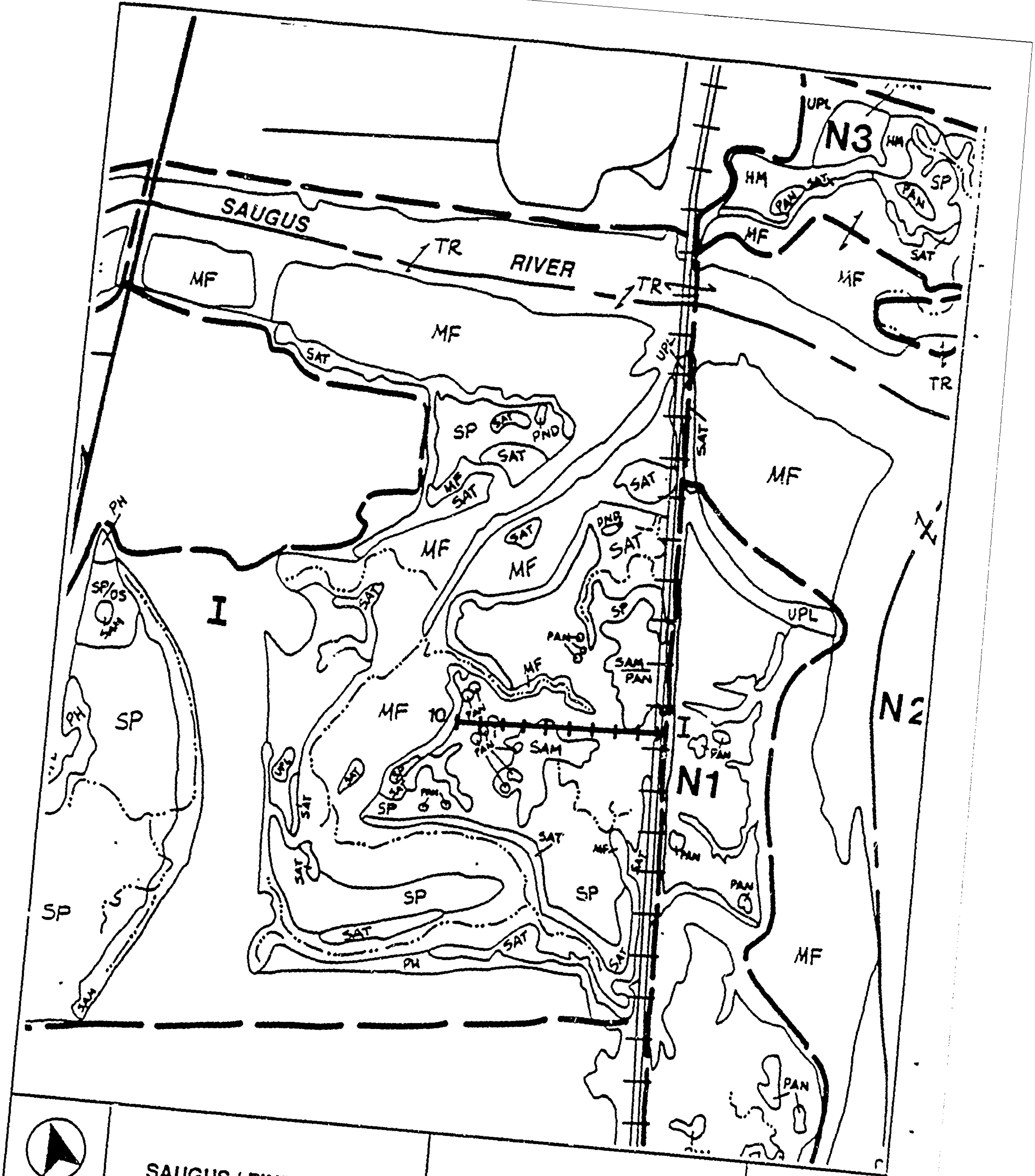
The K1 transect begins at the wetland-upland boundary in the west-central portion of the compartment and extends toward the southeast (Figure K12). The transect largely passes through the undifferentiated high marsh cover type; this is reflected in the data, with 25 species recorded within the 30 $1m^2$ plots covering an average of 87% of the area inventoried (Table K13). *Spartina patens* and *Distichlis spicata* are again the most common species along the transect, occurring in 93% and 87% of the plots, respectively, with mean cover values of 35% and 34%, respectively. No *Spartina alterniflora* occurred within the plots. A number of species not typically found in abundance on salt marshes occurred along the transect, including *Agrostis stolonifera*, *Agropyron pungens*, *Spartina pectinata*, *Teucrium canadense*, *Juncus balticus*, *Hierochloe odorata*, *Myrica pennsylvanica* and *Solidago rugosa*. It is

Table K11. **Plant Community Composition Data Along Compartment B Transect**

Species	Percent Frequency of Occurrence[1]	Mean Percent Cover ($\pm$ S.D.)[2]	Mean Height cm ($\pm$ S.D.)[3]
Distichlis spicata	100	42 $\pm$ 22	47 $\pm$ 9
Spartina patens	91	49 $\pm$ 25	49 $\pm$ 12
Spartina alterniflora	33	14 $\pm$ 28	120 $\pm$ 11
Solidago sempervirens	16	1 $\pm$ 4	59 $\pm$ 14
Atriplex patula	13	0.4 $\pm$ 1	—
Polygonum ramosissimum	4	1 $\pm$ 3	70
Iva frutescens	4	0.4 $\pm$ 2	27
Salicornia europea	4	0.2 $\pm$ 1	28

Number of species observed in transect = 8
Number of $1m^2$ plots in transect = 24
Mean total percent cover for all plots = 85 $\pm$ 30

[1] Percent Frequency of Occurrence = $1m^2$ plots in which a species occurs ÷ total number of $1m^2$ plots in transect.
[2] Mean Percent Cover = summation of percent cover for each species for all $1m^2$ plots in transect ÷ total number of $1m^2$ plots in transect.
[3] Mean Height = summation of heights for a species ÷ number of $1m^2$ plots in which the species occurs. (No heights were measured for species with less than 5% cover.)



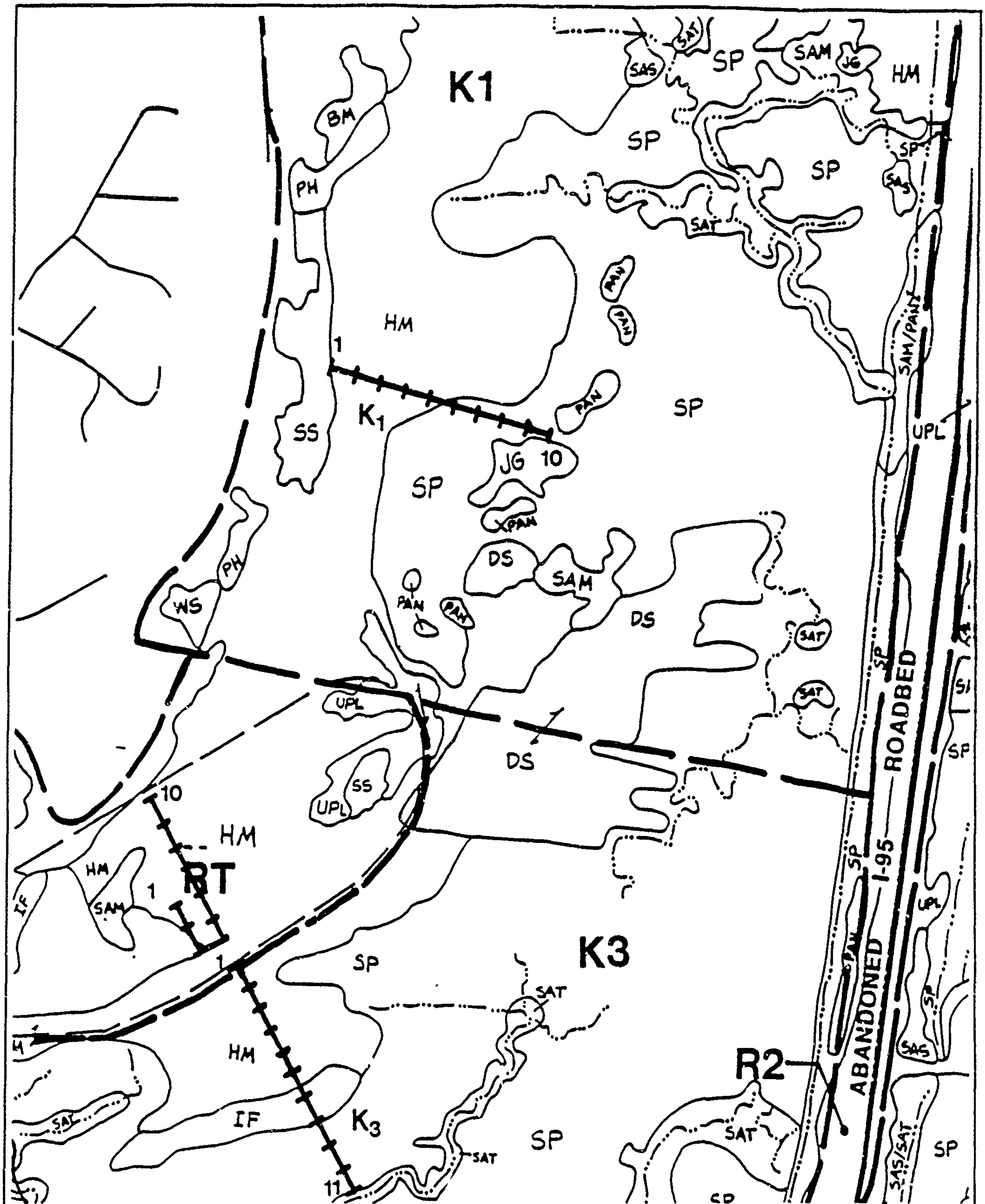
SCALE: 1" = 500'	SAUGUS / PINES RIVERS ESTUARINE WETLANDS STUDY	COMPARTMENT I VEGETATION TRANSECT LOCATION	Figure K11

Table K12. **Plant Community Composition Data Along Compartment I Transect**

Species	Percent Frequency of Occurrence[1]	Mean Percent Cover (± S.D.)[2]	Mean Height cm (± S.D.)[3]
Spartina patens	73	53 ± 43	37 ± 4
Spartina alterniflora	67	35 ± 36	54 ± 25
Salicornia europea	53	2 ± 3	30 ± 7
Atriplex patula	33	1 ± 2	24
Puccinellia maritima	27	3 ± 5	43 ± 8
Suaeda maritima	3	0.2 ± 0.9	19
Limonium nashii	3	0.1 ± 0.5	—

Number of species observed in transect = 7
Number of $1m^2$ plots in transect = 30
Mean total percent cover for all plots = 88 ± 24

[1]Percent Frequency of Occurrence = $1m^2$ plots in which a species occurs ÷ total number of $1m^2$ plots in transect.
[2]Mean Percent Cover = summation of percent cover for each species for all $1m^2$ plots in transect ÷ total number of $1m^2$ plots in transect.
[3]Mean Height = summation of heights for a species ÷ number of $1m^2$ plots in which the species occurs. (No heights were measured for species with less than 5% cover.)



SCALE:
1" = 500'

SAUGUS / PINES RIVERS
ESTUARINE WETLANDS STUDY

COMPARTMENTS K_1, K_3 & RT
VEGETATION TRANSECT
LOCATIONS

Figure K12

Table K13 Plant Community Composition Data Along Compartment K1 Transect

Species	Percent Frequency of Occurrence[1]	Mean Percent Cover ($\pm$ S.D.)[2]	Mean Height cm ($\pm$ S.D.)[3]
Spartina patens	93	35 $\pm$ 23	39 $\pm$ 7
Distichlis spicata	87	34 $\pm$ 30	31 $\pm$ 5
Juncus gerardii	70	11 $\pm$ 12	32 $\pm$ 7
Panicum virgatum	40	10 $\pm$ 17	87 $\pm$ 35
Agrostis stolonifera	40	7 $\pm$ 15	45 $\pm$ 7
Solidago sempervirens	37	2 $\pm$ 4	29 $\pm$ 4
Teucrium canadense	23	2 $\pm$ 7	43 $\pm$ 11
Triglochin maritima	20	1 $\pm$ 4	44 $\pm$ 12
Convolvulus sepium	17	1 $\pm$ 2	43 $\pm$ 26 (vine)
Limonium nashii	17	1 $\pm$ 1	—
Spartina pectinata	13	2 $\pm$ 6	131 $\pm$ 9
Salicornia europea	13	1 $\pm$ 3	22 $\pm$ 6
Juncus balticus	13	1 $\pm$ 2	70 $\pm$ 20
Euthamia tenuifolia	13	0.5 $\pm$ 1	80
Suaeda maritima	13	0.4 $\pm$ 1	—
Myrica pensylvanica	10	2 $\pm$ 6	48 $\pm$ 20
Iva frutescens	10	1 $\pm$ 3	63 $\pm$ 4
Atriplex patula	10	0.3 $\pm$ 1	—
Rosa sp.	7	2 $\pm$ 7	59 $\pm$ 1
Spiraea latifolia	7	1 $\pm$ 5	50
Agropyron pungens	7	0.3 $\pm$ 1	68
Unidentified grass	7	0.3 $\pm$ 1	67
Unidentified herb	3	0.2 $\pm$ 1	—
Solidago rugosa	3	0.1 $\pm$ 1	—
Hierochloe odorata	3	0.1 $\pm$ 1	—

Number of species observed in transect = 25
Number of $1m^2$ plots in transect = 30
Mean total percent cover for all plots = 87 $\pm$ 8

[1]Percent Frequency of Occurrence = $1m^2$ plots in which a species occurs ÷ total number of $1m^2$ plots in transect.
[2]Mean Percent Cover = summation of percent cover for each species for all $1m^2$ plots in transect ÷ total number of $1m^2$ plots in transect.
[3]Mean Height = summation of heights for a species ÷ number of $1m^2$ plots in which the species occurs. (No heights were measured for species with less than 5% cover.)

possible that these species reflect a change in hydrology (decreased frequency and duration of flooding) brought about by road construction and other disturbances.

The soils along the K1 transect appear to be highly decomposed, sapric organics with organic matter content ranging from 4-61% and a mean organic matter content of 16%. By technical definition, most of the samples analyzed are actual mineral soils, as the organic matter content is less than 20%. Mean grain sizes are 49% sand, 21% silt and 14% clay. This is one of the highest mineral contents of the seven salt marsh transects.

Compartment K3 Transect

Eleven 5m x 5m sample stations were established along the K3 transect. All of the stations are located south of the old Saugus Race Track (Figure K12). The northernmost station (K3-1) was established at the edge of the salt marsh community/upland edge at the Saugus Race Track. Three small streams were crossed along the transect route. These streams flow through the salt marsh and into a tributary of the Pines River. Three of the sample stations crossed the streams which contained several inches of water during high tide periods. The transect ended in the salt marsh at the 300 meter distance point.

The salt marsh along the transect is dominated by Distichlis spicat and Spartina patens, with mean percent cover values of 54 and 41, respectively (Table K14). Distichlis occurred within all 33 $1m^2$ plots, while Spartina patens was encountered nearly as commonly (percent frequency of occurrence of 91). Other species commonly occurring in the transect include Puccinellia maritima which has a 55 percent frequency of occurrence but covered only 8% of the plot area and Atriplex patula, with a 39 percent frequency of occurrence, but a mean percent cover of only 2. Thus, a fairly uniform community of Distichlis and Spartina characterizes this transect.

The soils along the K3 transect are highly decomposed, sapric organics with a mean organic content of 25% and a range of 5-59%. The mean grain sizes are 34% sand and 26% for both silt and clay.

Compartment L2 Transect

The transect in the L2 Compartment begins at the wetland/upland boundary on the northwest corner of the upland island adjacent to Route 107 and traverses the marsh in a northwesterly direction (Figure K13). The vegetation in this compartment is presumed to be similar to that of Compartment L1. Nine 5m x 5m sample stations were established along the transect, with the last station (L2-9) located 13m from the edge of an unnamed creek. The transect intersected several man-created ditches and one tidal creek. The ditches and tidal creek flow into the unnamed creek which is a tributary to the Pines River.

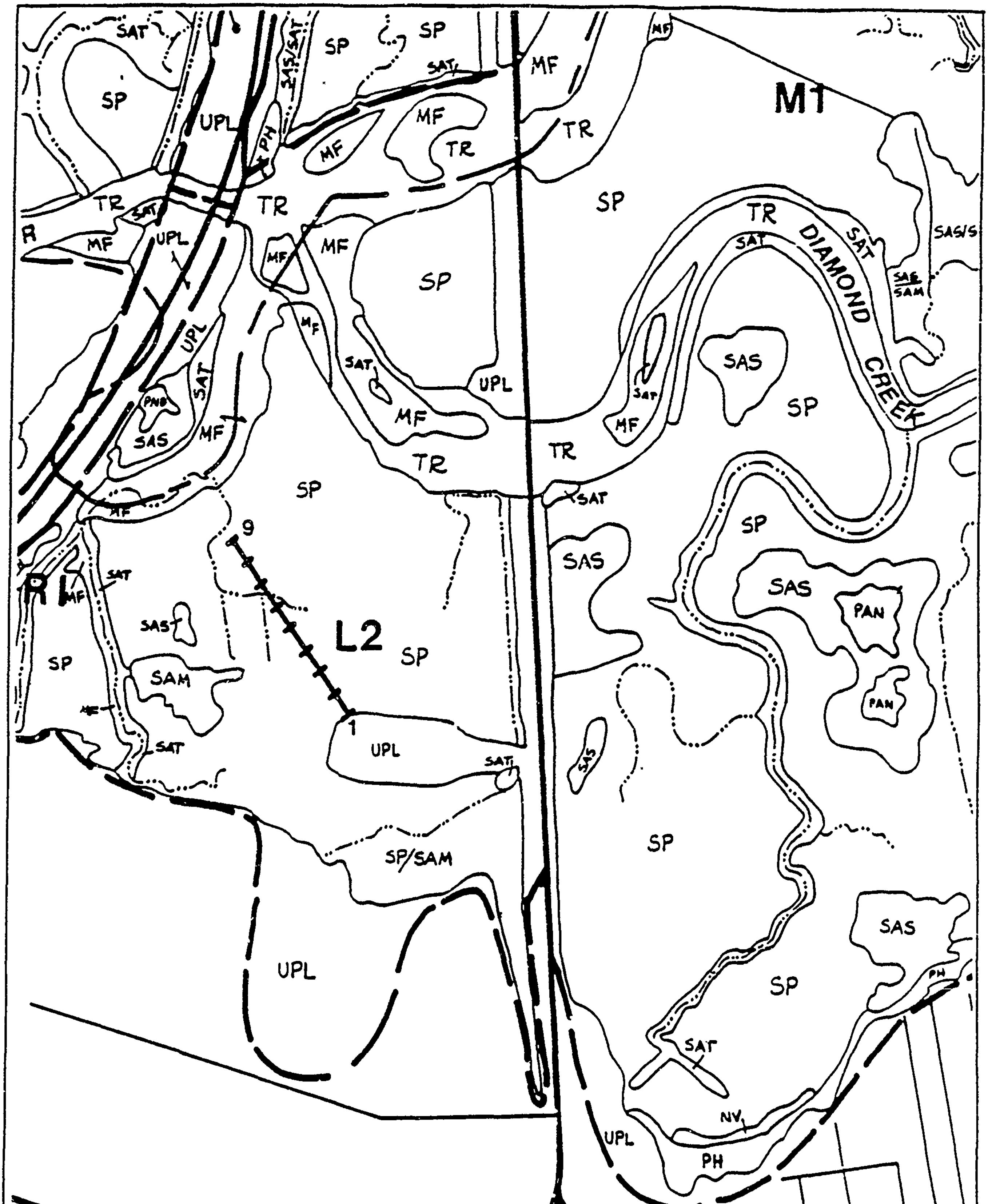
The plant composition identified in the 27 $1m^2$ plots substantiate the cover type delineation of this high salt marsh (Table K15). had a 78% frequency of occurrence and a mean cover of 58%. Tall (90cm height)

Table K14. **Plant Community Composition Data Along Compartment K3 Transect**

Species	Percent Frequency of Occurrence[1]	Mean Percent Cover ($\pm$ S.D.)[2]	Mean Height cm ($\pm$ S.D.)[3]
Distichlis spicata	100	54 $\pm$ 21	36 $\pm$ 7
Spartina patens	91	41 $\pm$ 29	43 $\pm$ 8
Puccinellia martima	55	8 $\pm$ 13	56 $\pm$ 9
Atriplex patula	39	2 $\pm$ 3	31 $\pm$ 1
Salicornia europea	24	1 $\pm$ 1	20
Spartina alterniflora	21	2 $\pm$ 5	64 $\pm$ 17
Limonium nashii	12	1 $\pm$ 3	41 $\pm$ 18
Suaeda maritima	12	0.4 $\pm$ 1	26
Teucrium canadense	9	0.5 $\pm$ 2	45
Juncus balticus	6	2 $\pm$ 9	76 $\pm$ 20
Juncus gerardii	6	1 $\pm$ 7	48 $\pm$ 3
Triglochin maritima	6	1 $\pm$ 3	50
Solidago sempervirens	6	0.2 $\pm$ 1	30
Agropyron pungens	3	1 $\pm$ 3	71

Number of species observed in transect = 14
Number of $1m^2$ plots in transect = 33
Mean total percent cover for all plots = 95 $\pm$ 6

[1]Percent Frequency of Occurrence = $1m^2$ plots in which a species occurs ÷ total number of $1m^2$ plots in transect.
[2]Mean Percent Cover = summation of percent cover for each species for all $1m^2$ plots in transect ÷ total number of $1m^2$ plots in transect.
[3]Mean Height = summation of heights for a species ÷ number of $1m^2$ plots in which the species occurs. (No heights were measured for species with less than 5% cover.)



SCALE: 1" = 500'	SAUGUS / PINES RIVERS ESTUARINE WETLANDS STUDY	COMPARTMENT L_2 VEGETATION TRANSECT LOCATION	Figure K13

Table K15. **Plant Community Composition Data Along Compartment L2 Transect**

Species	Percent Frequency of Occurrence[1]	Mean Percent Cover ($\pm$ S.D.)[2]	Mean Height cm ($\pm$ S.D.)[3]
Spartina patens	78	58 $\pm$ 41	38 $\pm$ 7
Spartina alterniflora	70	23 $\pm$ 31	90 $\pm$ 31
Atriplex patula	63	2 $\pm$ 3	31 $\pm$ 6
Salicornia europea	48	2 $\pm$ 2	33 $\pm$ 10
Suaeda maritima	33	1 $\pm$ 3	36
Distichlis spicata	30	6 $\pm$ 14	36 $\pm$ 3
Puccinellia maritima	15	3 $\pm$ 8	41 $\pm$ 11
Limonium nashii	15	2 $\pm$ 7	40 $\pm$ 14
Amoracia lapathifolia	4	1 $\pm$ 2	130
Solidago sempervirens	4	0.2 $\pm$ 1	61
Agrostis stolonifera	4	0.2 $\pm$ 1	44

Number of species observed in transect = 11
Number of $1m^2$ plots in transect = 27
Mean total percent cover for all plots = 88 $\pm$ 24

[1] Percent Frequency of Occurrence = $1m^2$ plots in which a species occurs ÷ total number of $1m^2$ plots in transect.
[2] Mean Percent Cover = summation of percent cover for each species for all $1m^2$ plots in transect ÷ total number of $1m^2$ plots in transect.
[3] Mean Height = summation of heights for a species ÷ number of $1m^2$ plots in which the species occurs. (No heights were measured for species with less than 5% cover.)

Spartina alterniflora was the next most abundant species and occurred in 70% of the plots with a mean cover of 23%. This species occurred primarily along the edges of the deeper man-created ditches and along the tidal creek. *Distichlis spicata* had a relatively low mean cover of only 6% and occurred in only 30% of the plots. A total of eleven plant species were identified in the plots along the transect and the mean total percent cover for all 27 plots was 88%.

The soils along the L2 transect are technically mineral soils, but appear to be highly decomposed sapric organics, based on field examination. The mean organic matter content is 15% dry weight, with a range of 4-27%. Mean grain sizes of the soils are 12% sand, 46% silt and 35% clay.

Compartment M1 Transect

The transect established within Compartment M1 began along the southwest edge of Oak Island and extended west 300m to within 65m of Diamond Creek (Figure K14). Compartment M2 was considered to be similar to Compartment M1. The transect began in a disturbed edge community which contributed several non-salt marsh species and increased species richness along the transect to 14. At least 10 ditches crossed the transect, with 6 1m2 plots containing portions of ditches. The cover type unit which most of the transect traversed is undifferentiated high salt marsh, although a sizable unit of short *Spartina alterniflora* is crossed as well.

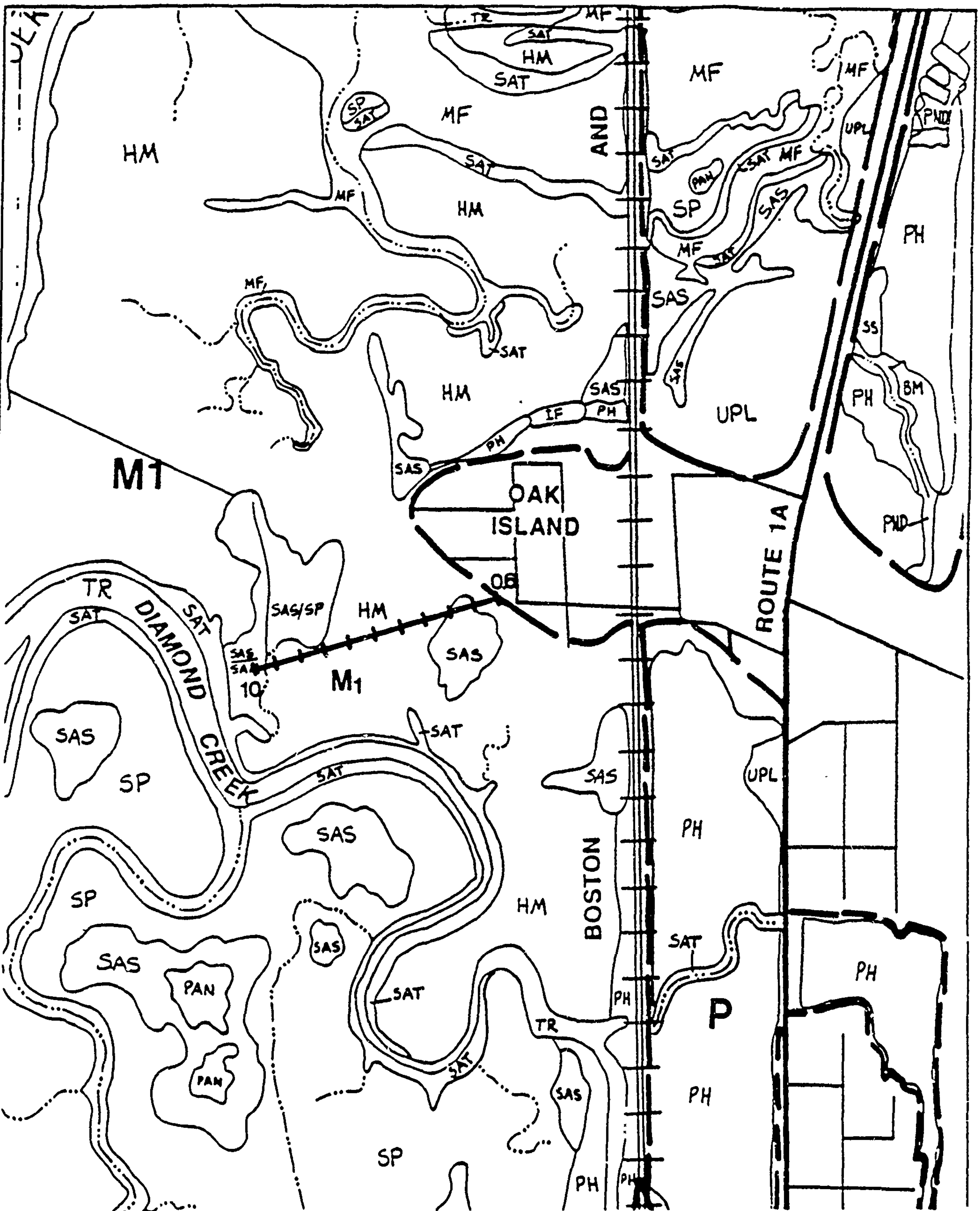
Within the 33 $1m^2$ plots sampled, *Spartina patens* occurred most frequently (91% of plots) and provided the most extensive cover (mean of 66%) (Table K16). *Spartina alterniflora* occurred in 58% of the plots and on average covers 24% of the area; the mean height of 64cm reflects the occurrence of short *Spartina alterniflora* in poorly drained depressed pockets, yet with taller individuals growing along the ditches. Glasswort (*Salicornia europea*) and *Atriplex patula* were frequently encountered (79% and 70% frequency of occurrence, respectively) yet because of their small stature neither provides much cover (4% each). Overall vegetative cover along the transect exceeds 94%.

Soils along this transect also consist of highly decomposed, sapric organics, with a range of organic matter content of 16-44%. The mean grain sizes are 15% sand, 30% silt and 35% clay.

Compartment RT Transect

The transect located within the area encircled by the Old Saugus Race Track traversed southward through the central portion of the compartment (Figure K12). Since the distance across the compartment in this area is only 200m, a second 100m-long transect was established parallel to the first to enable ten 5m x 5m stations to be sampled.

Similar to the transect through K1, a relatively high species richness (n = 18) within the RT transect is believed to be influenced by the disturbed hydrology created within the confines of the Track (Table K17). Marsh hydrology here may also be influenced by the I-95 embankment and roads



SCALE:
1" = 500'

SAUGUS / PINES RIVERS
ESTUARINE WETLANDS STUDY

COMPARTMENT M_1
VEGETATION TRANSECT
LOCATION

Figure K14

Table K16. Plant Community Composition Data Along Compartment M1 Transect

Species	Percent Frequency of Occurrence[1]	Mean Percent Cover (± S.D.)[2]	Mean Height, cm (± S.D.)[3]
Spartina patens	91	66 ± 35	34 ± 7
Salicornia europea	79	4 ± 4	27 ± 5
Atriplex patula	70	4 ± 6	29 ± 7
Spartina alterniflora	58	24 ± 29	64 ± 21
Distichlis spicata	45	4 ± 6	32 ± 9
Limonium nashii	12	0.7 ± 2	30 ± 21
Agropyron pungens	9	5 ± 18	102 ± 8
Amoracia lapathifolia	9	2 ± 10	98 ± 25
Solidago sempervirens	6	2 ± 9	63 ± 4
Chenopodium album	6	0.4 ± 2	25
Iva frutescens	3	0.6 ± 3	130
Parthenocissus quinquefolia	3	0.3 ± 2	25
Artemesia biennis	3	0.1 ± 0.5	—
Unidentified grass	3	0.1 ± 0.5	—

Number of species observed in transect = 14
Number of $1m^2$ plots in transect = 33
Mean total percent cover for all plots = 94.3 ± 13

[1] Percent Frequency of Occurrence = $1m^2$ plots in which a species occurs ÷ total number of $1m^2$ plots in transect.
[2] Mean Percent Cover = summation of percent cover for each species for all $1m^2$ plots in transect ÷ total number of $1m^2$ plots in transect.
[3] Mean Height = summation of heights for a species ÷ number of $1m^2$ plots in which the species occurs. (No heights were measured for species with less than 5% cover.)

Table K17. **Plant Community Composition Data Along Compartment RT Transect**

Species	Percent Frequency of Occurrence[1]	Mean Percent Cover ($\pm$ S.D.)[2]	Mean Height cm ($\pm$ S.D.)[3]
Distichlis spicata	90	25 $\pm$ 21	34 $\pm$ 11
Spartina patens	70	29 $\pm$ 28	37 $\pm$ 13
Iva frutescens	40	9 $\pm$ 11	65 $\pm$ 22
Juncus gerardii	40	10 $\pm$ 15	33 $\pm$ 5
Juncus balticus	23	13 $\pm$ 19	77 $\pm$ 19
Spartina alterniflora	20	4 $\pm$ 9	55 $\pm$ 17
Unidentified grass	17	6 $\pm$ 10	48
Salicornia europea	17	8 $\pm$ 10	30
Panicum virgatum	10	14 $\pm$ 27	107 $\pm$ 6
Vicia cracca	10	8 $\pm$ 11	70 $\pm$ 5
Atriplex patula	10	8 $\pm$ 10	—
Solidago sempervirens	10	6 $\pm$ 9	30
Agrostis stolonifera	10	3 $\pm$ 6	45
Suaeda maritima	7	7 $\pm$ 10	—
Calystegia sepium	3	0.2 $\pm$ 0.6	80
Rosa sp.	3	0.1 $\pm$ 0.5	—
Triglochin maritima	3	0.1 $\pm$ 0.5	—
Limonium nashii	3	0.1 $\pm$ 0.5	—

Number of species observed in transect = 18
Number of $1m^2$ plots in transect = 30
Mean total percent cover for all plots = 79 $\pm$ 27

[1] Percent Frequency of Occurrence = $1m^2$ plots in which a species occurs ÷ total number of $1m^2$ plots in transect.
[2] Mean Percent Cover = summation of percent cover for each species for all $1m^2$ plots in transect ÷ total number of $1m^2$ plots in transect.
[3] Mean Height = summation of heights for a species ÷ number of $1m^2$ plots in which the species occurs. (No heights were measured for species with less than 5% cover.)

constructed in the marsh downstream. *Spartina patens* and *Distichlis spicata* continue to be the dominant species within the area sampled, with 70% and 90% frequency of occurrence and 29% and 25% mean cover values, respectively. *Iva frutescens* and *Juncus gerardii* are also relatively common (40% of plots, 9-10% cover) typically growing on slightly higher berms along ditches. The presence of *Juncus balticus* in 23% of the plots is perhaps indicative of the altered hydrology and high sand content. *Spartina alterniflora* is nearly as common (20% frequency), with the average height of 55cm again indicating mixtures of tall and short forms rather than an abundance of mid-height individuals. Small areas of sparsely vegetated "near-pannes" composed of short *Spartina alterniflora*, *Salicornia europea*, *Suaeda maritima* and algal mats are widely distributed through the compartment, and are reflected in the data. Overall vegetative cover along the transect is nearly 80%.

Soils along the transect are mostly mineral soils, by technical definition, based on the low organic matter content. The mean organic matter content is 14% with a range of 6-51%. The mean grain sizes of these soils are 45% sand, 23% silt and 16% clay. The high mineral component of these soils is similar to the soils in the K1 transect and may be a result of increased decomposition of organic matter from altered hydrology in the area.

Tidal Freshwater/Brackish Marsh

Introduction

Odum et al. (1984) in "The Ecology of Tidal Freshwater Marshes of the United States East Coast: A Community Profile" define tidal freshwater wetlands as those wetlands "located upstream from tidal saline wetlands and downstream from nontidal freshwater wetlands and characterized by (1) near freshwater conditions (average annual salinity of 0.5 ppt or below except during periods of extended drought), (2) plant and animal communities dominated by freshwater species, and (3) a daily, lunar tidal fluctuation." They are dominated by a large and diverse group of broad-leafed plants, grasses, rushes, shrubs and herbaceous plants in contrast to salt marshes which are dominated by estuarine marsh grasses (*Spartina* spp.) (Odum et al., 1984).

Odum et al. (1984) developed a classification of eight major floristic associations in tidal freshwater wetlands. Of these eight, two are found in the Saugus/Pines Rivers system: Cattail Community Type and Mixed Aquatic Community Type.

The Cattail Community Type is the more common in the Study Area. It is described as occurring in dense monospecific stands or with one or more associates and occurs with common reed (*Phragmites australis*) in disturbed areas (Odum et al., 1984). All of these compositional types are present in the Study Area.

The more varied Mixed Aquatic Community Type consists of an extremely variable mix of freshwater marsh vegetation and occurs in the upper intertidal zone of the marsh (Odum et al., 1984). Species listed as common to this community type and present in the Study Area marsh are arrow-arum

(*Peltandra virginica*), rose mallow (*Hibiscus palustris*) , smartweeds (*Polygonum* spp.), cattails (*Typha* spp.), purple loosestrife (*Lythrum salicaria*) and jewelweed (*Impatiens capensis*). A small area of this type is present just north of Hamilton Street in Saugus. Saltmeadow grass (*Spartina patens*) and saltmarsh cordgrass (*Spartina alterniflora*) are also present in this area.

Zonation in freshwater tidal marshes is less distinct than in salt marshes, but does occur. Metzler and Rozza (1982) (Odum et al., 1984) describe 5 zones (SUBTIDAL, LOWER INTERTIDAL, MID-TIDAL MARSH BORDER, HIGH MARSH, UPLAND) in a Connecticut tidal freshwater marsh. Factors controlling plant species distribution are the frequency and duration of flooding, substrate characteristics, current flow, salinity, physiological capability to exist with anaerobic toxins, interspecific competition and allelopathy (the supression of growth of one plant species by another due to the release of toxic substances). The upper limit of tidal freshwater marshes is typically at the mean high water line where shrub and forest vegetation begin to dominate. Slopes are greatest in the Subtidal and Lower Intertidal zones. The elevation continues to increase in the relatively narrow Mid-tidal Marsh Border zone, then decreases forming a slight levee. The elevation then gently increases through the High Marsh zone to the upland edge (Odum et al., 1984).

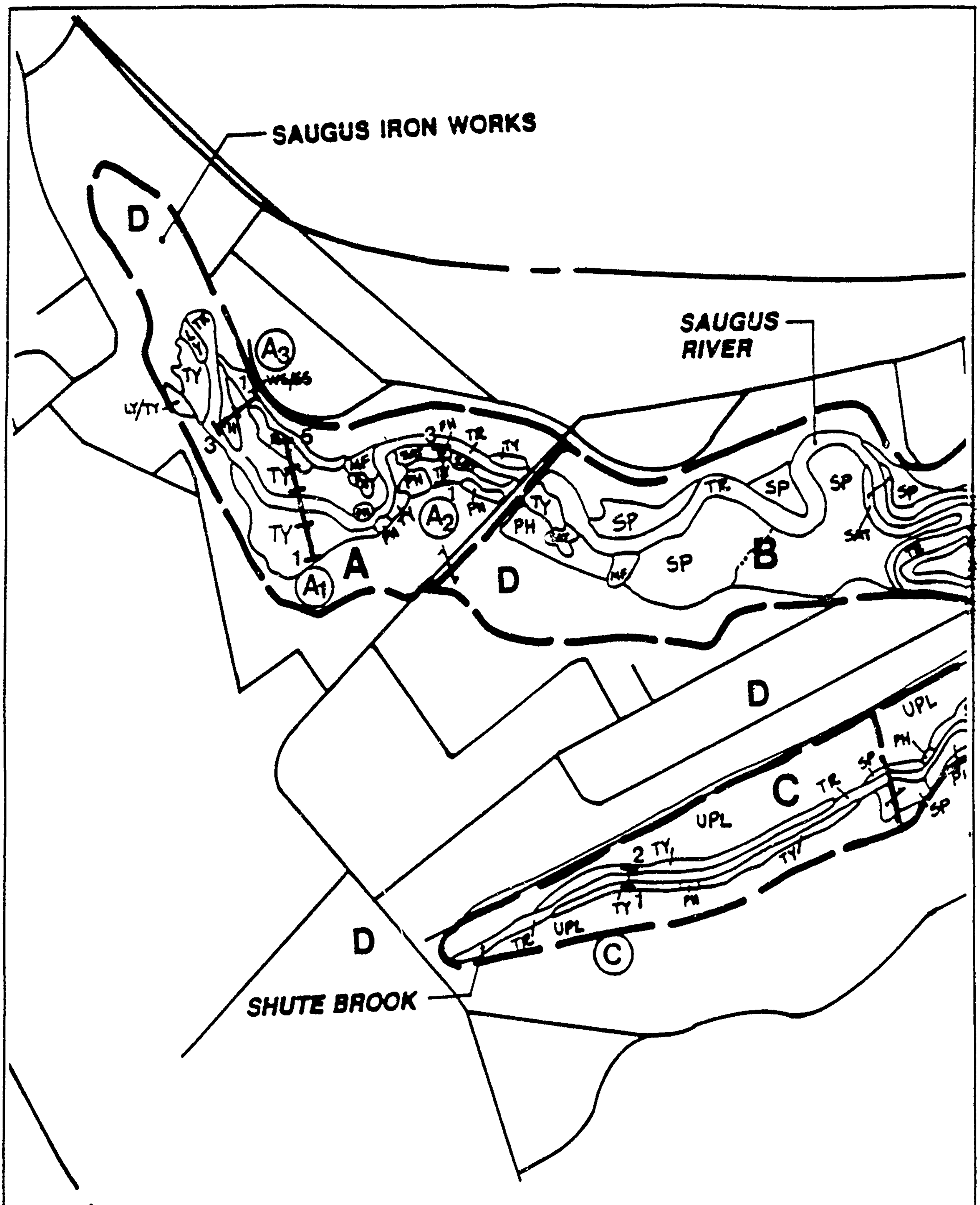
Methodology

In order to document in detail the plant species composition and zonation of the Study Area tidal/brackish freshwater marshes quantitative botanical measures were obtained along transects running perpendicular to the rivers. In addition, soil samples, salinity readings and land surface elevation measurements were obtained along each transect to assess plant species composition relative to physical variables.

Transect locations were initially established in a stratified random fashion on aerial photographs by selecting easily identifiable landmarks which could be located in the field as starting points, and extending the transects across the marsh either perpendicular to the river or to specified features. Transects were subsequently laid out in the field to approximate the photographic delineations as closely as possible. Transect locations are shown on Figure K15. Three transects were established in Compartment A (A1, A2, A3) across the Saugus River and one was established in Compartment C across Shute Brook.

Along each transect, 5m x 5m sample stations were established at 30 meter (98 foot) intervals. Within each station, by convention, the northwest, northeast, and southeast corners were selected for plots (each 2m x 0.5m) for obtaining plant composition data (it was assumed that each transect was oriented toward due north for this purpose). Within each plot, all plants were identified to species, percent cover was estimated for each species and for the entire plot, maximum height was measured for each species comprising greater than 5% cover, and the stem density of each species was counted.

At the center of each 5m x 5m station, a soil sample from the top 10" of the soil profile was obtained using a 3-inch diameter Dutch auger.



SCALE: 1" = 500'

SAUGUS / PINES RIVERS
ESTUARINE WETLANDS STUDY

COMPARTMENTS A & C
VEGETATION TRANSECT
LOCATIONS

Figure K15

Soil samples were visually characterized by degree of decomposition for organic soils (sapric, hemic, fibric) or texture for mineral soils and bagged for later analysis of percent organic matter and grain size. Percent organic matter was obtained by drying the samples at 103°C and then measuring weight loss upon ignition. Particle size analysis was accomplished by sieving the mineral component of the samples after removing the organic matter by digestion with hydrogen peroxide. Large pieces of organic matter that were not digested by this process, such as twigs and small sticks were physically removed from the samples before analyzing for grain size.

Elevation data were subsequently collected along each transect using conventional surveying equipment (transit and rod). Elevations of individual plots, tops and toes of banks, ditches and rivers, and other notable features along each transect were obtained relative to the National Geodetic Vertical Datum (NGVD).

Free soil water salinity and conductivity were measured at the center of each sample station on one date during low tide. Perforated PVC pipes were installed into holes augured 3 feet deep, and water levels allowed to stabilize. Measurements were obtained using a YSI Model 33 Salinity, Conductivity and Temperature portable meter with the probe held roughly 10cm below the stabilized water level.

Results

The following sections briefly describe the locations of the four transects in Compartments A and C, in the Upper Saugus River and Shute Brook, and the results of the examination of vegetation composition, soils and salinity.

Upper Saugus River, Transect A1

Transect A1 was established through the central portion of Compartment A on the upper Saugus River (Figure K15). Five 5m x 5m sample stations were established along the transect. Two of these stations were located on the south side of the Saugus River and three on the north side. The northernmost sample station (A1-5) was established at the edge of the marsh community and is therefore less than 30 meters north of the station to the south (A1-4). The transect crosses the Saugus River at a point where it is approximately 60 feet wide. The banks between the Saugus River and the adjacent marsh are about one foot high. The transect crosses two small streams that flow through the marsh and into the Saugus River, one on the north side of the river and one to the south. A depression approximately 15 feet in diameter is located along the southern portion of the transect. This area of exposed organic soils lacks vegetation and contained several inches of standing water at the times of the site visits. None of the sample stations were located in the streams or in the unvegetated depression.

The marsh along the A1 transect is dominated by Typha spp. which has a mean percent cover of 63 and a mean density of 41 stems/m2 (Table K18). Lythrum salicaria has the second highest frequency of occurrence in the sample plots (33%), but has a relatively low mean percent cover (3%).

Table K18 Plant Community Composition Data Along Transect A1, Upper Saugus River

Species	Percent Frequency of Occurrence[1]	Mean Percent Cover (± S.D.)[2]	Mean Height cm (± S.D.)[3]	Mean Stem Density stems/m^2 (± S.D.)[4]
Typha spp.	100	63 ± 18	217 ± 23	41.0 ± 23.8
Lythrum salicaria	33	3 ± 6	142 ± 4	1.1 ± 2.6
Polygonum hydropiper	27	1 ± 2	73	0.5 ± 1.1
Phragmites australis	13	4 ± 13	280 ± 7	1.5 ± 4.3
Phalaris arundinacea	13	4 ± 12	109 ± 6	12.0 ± 35.6
Spartina alterniflora	13	1 ± 3	194	0.5 ± 1.6
Unidentified herb	13	0.4 ± 1	—	0.4 ± 1.1
Toxicodendron radicans	7	4 ± 15	45	2.3 ± 9.0
Myrica gale	7	1 ± 5	134	0.1 ± 0.3
Lycopus americanus	7	1 ± 3	112	0.4 ± 1.6
Carex stricta	7	1 ± 3	83	0.1 ± 0.5
Solanum dulcamara	7	0.3 ± 1	118	0.1 ± 0.5
Carex sp.	7	0.3 ± 1	135	0.6 ± 2.3
Peltandra virginica	7	0.2 ± 1	—	0.1 ± 0.3
Sparganium sp.	7	0.2 ± 1	—	0.1 ± 0.3
Solidago sp.	7	0.2 ± 1	—	0.1 ± 0.3
Unidentified COMPOSITAE	7	0.2 ± 1	—	0.3 ± 1.3

Number of species observed in transect = 17
Number of $1m^2$ plots in transect = 15
Mean total percent cover for all plots = 74 ± 12

[1]Percent Frequency of Occurrence = $1m^2$ plots in which a species occurs ÷ total number of $1m^2$ plots in transect.
[2]Mean Percent Cover = summation of percent cover for each species for all $1m^2$ plots in transect ÷ total number of $1m^2$ plots in transect.
[3]Mean Height = summation of heights for a species ÷ number of $1m^2$ plots in which the species occurs. (No heights were measured for species with less than 5% cover.)
[4]Mean Stem Density = total number of stems of a species along the transect ÷ total number of $1m^2$ plots in transect.

Interstitial salinity ranged from 0.3-2.2 ppt (see Table K23). Soils through the transect are highly decomposed sapric organics, with organic matter content ranging from 11-47%. The mean grain sizes of the soil samples taken along the transect, expressed as percentages of dry weight are 18% sand, 45% silt and 22% clay.

Elevation profiles for the south and north sides of the marsh are presented in Figures K16 and K17, respectively. On the south side of the transect, two prominent ditches are present with open water at elevations higher than the Saugus River at low tide. The flat, vegetated surface of the marsh extends from 4.2' - 4.6' NGVD, which is slightly below the mean high water level (5.0'). The marshes are therefore inundated during most high tides, which is typical of these marshes.

On the north side of the transect, there is only one prominent ditch. The surface of the vegetated marsh slopes gently toward the Saugus River with elevations ranging from 4.2' - 6.0' NGVD. _Typha_ spp. dominates throughout the transect, but other species, such as poison ivy (_Toxicodendron radicans_), become important at higher elevations (above mean high tide). Common reed (_Phragmites australis_) is common in the extreme upslope end of the marsh, adjacent to the freshwater shrub and wooded swamp. The low interstitial salinity in the upper end of the transect is likely the result of influence from the adjacent freshwater swamp and upland.

Upper Saugus River, Transect A2

Transect A2 was established in the southeast portion of Compartment A on the Saugus River roughly 90 meters (300 feet) above the Woodbury Avenue culvert (Figure K15). Three 5m x 5m sample stations were established on the southwest side of the Saugus River; no stations were located on the north side of the river since it borders directly on a steep upland bank on that side with little wetland vegetation at the edge. The transect extended out from a 2-3 foot high fill slope associated with a nearby parking lot; the first sample station was located at the wetland edge. The easternmost sample station was at the river's edge, slightly less than 30 meters (98 feet) from the central plot to avoid the deepwater habitat.

Typha spp. is again the dominant plant along the transect (Table K19). Adjacent to the river, _Spartina alterniflora_ and _Phragmites australis_ are dominant. Lythrum salicaria is the next most abundant species. A total of 14 species were encountered across the transect, with an overall vegetative cover of 78%.

Soils along the transect are highly decomposed sapric organics with mean organic content of 41% and with ranges from 15 - 59%. The mean grain sizes of the soils along the transect are 20% sand, 41% silt and 24% clay. Interstitial salinities were higher than in the previous transect (this transect is closer to the ocean), ranging from 2.8-4.1 ppt. Salinity within the Saugus River itself at low tide was lower (0.4 ppt).

The vertical profile cross-section for transect A2 is shown in Figure K18. A narrow ditch and an unvegetated depression are prominent

Figure K16

SAUGUS RIVER

TRANSECT NO. A-1 SOUTH

GROUND ELEVATION, VEGETATION PLOTS AND SALINITY

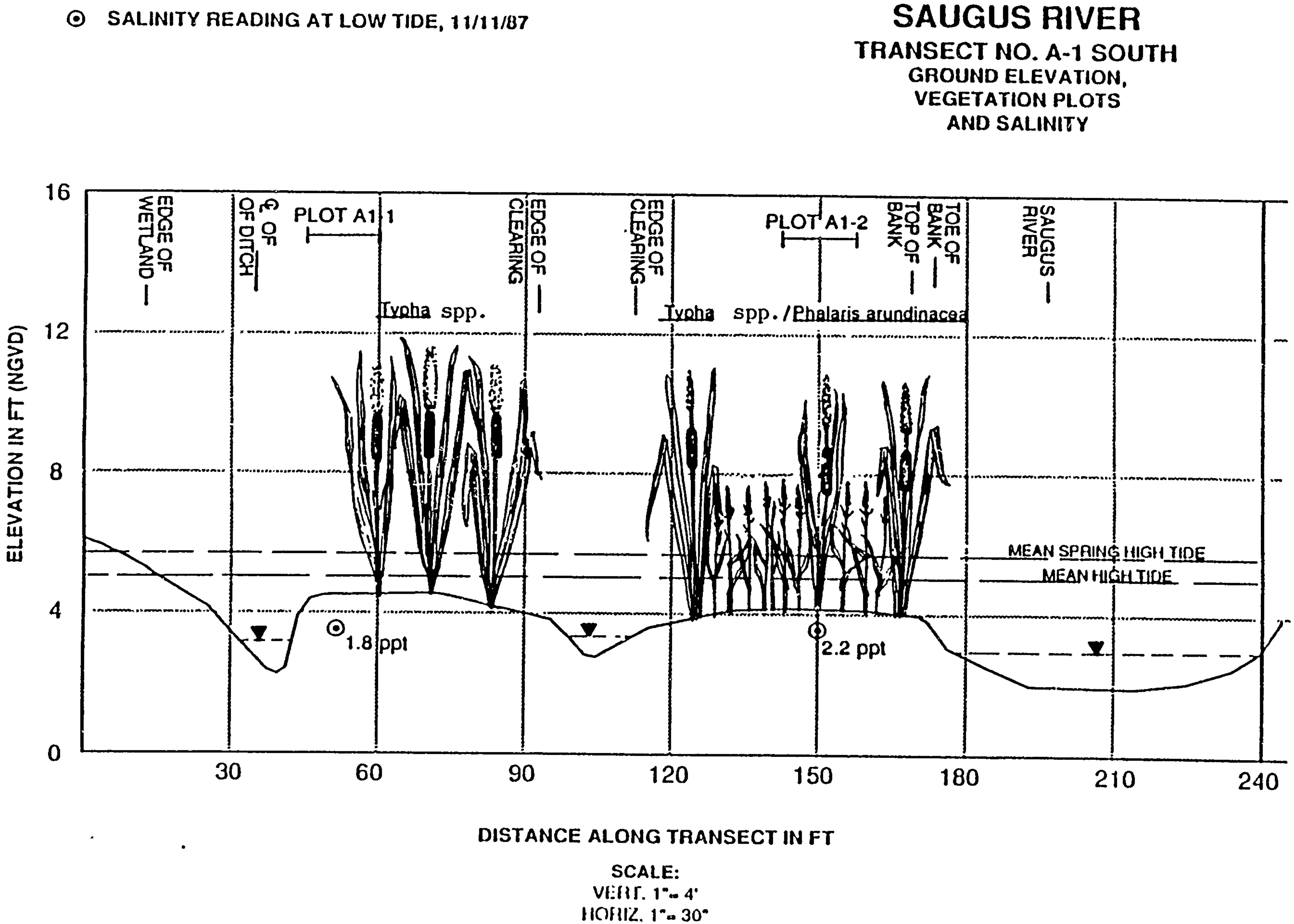


Figure K17

SAUGUS RIVER

TRANSECT NO. A-1 NORTH

GROUND ELEVATION, VEGETATION PLOTS AND SALINITY

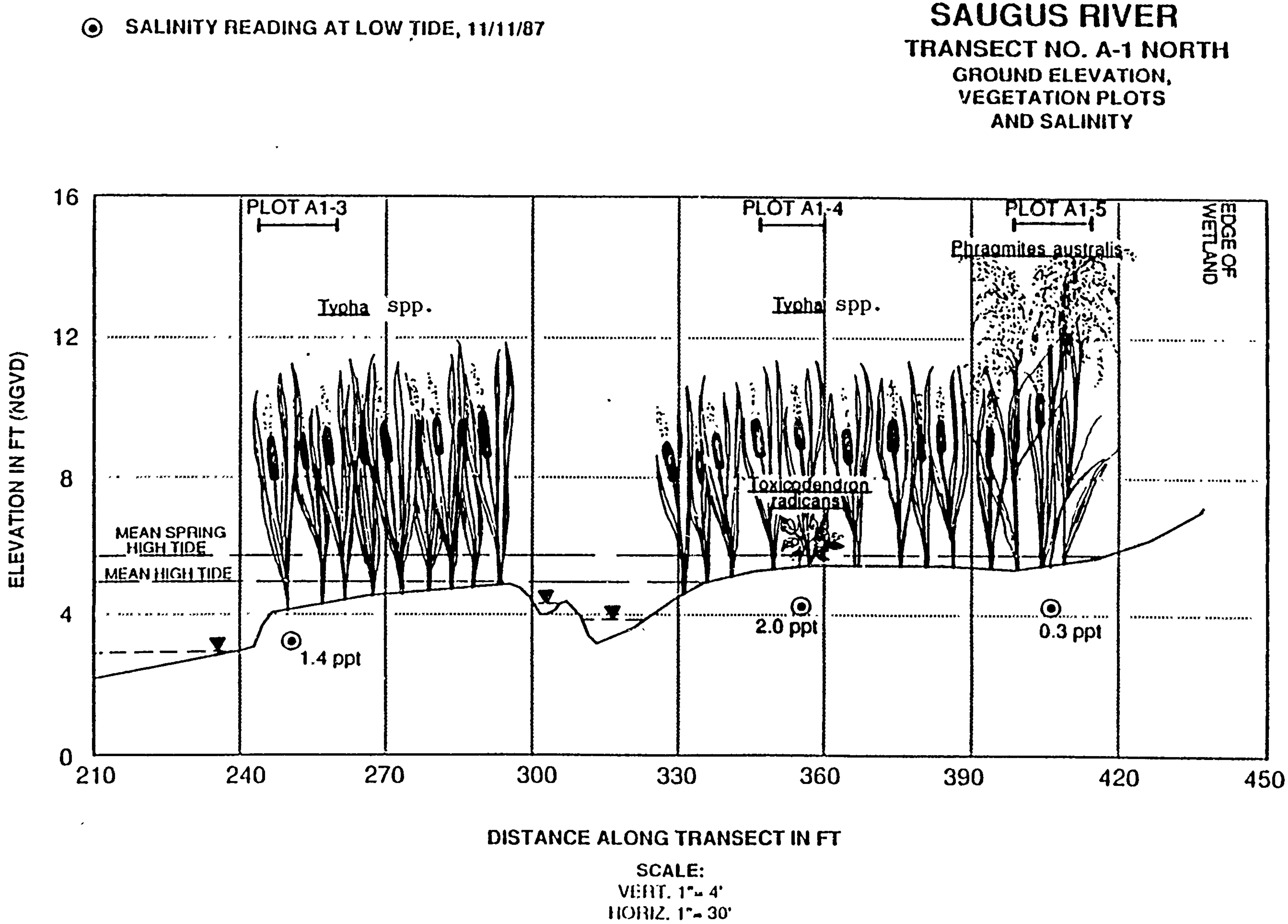


Table K19. **Plant Community Composition Data Along Transect A2, Upper Saugus River**

Species	Percent Frequency of Occurrence[1]	Mean Percent Cover (± S.D.)[2]	Mean Height cm (± S.D.)[3]	Mean Stem Density stems/m^2 (± S.D.)[4]
Typha spp.	67	43 ± 36	198 ± 27	34 ± 11.4
Spartina alterniflora	44	15 ± 25	167 ± 27	28.3 ± 43.3
Phragmites australis	22	14 ± 29	37 ± 5	8.1 ± 16.2
Lythrum salicaria	22	4 ± 9	186 ± 25	1.2 ± 2.5
Unidentified grass	22	2 ± 4	54 ± 5	50.6 ± 94.9
Scirpus robustus	22	1 ± 2	144	0.6 ± 1.1
Artemesia biennis	11	1 ± 3	237	0.7 ± 2.0
Armoracia lapathifolia	11	1 ± 3	128	1.0 ± 3.0
Euthamia tenuifolia	11	1 ± 2	110	0.6 ± 1.7
Convolvulus sepium	11	0.3 ± 1	—	0.1 ± 0.3
Atriplex patula	11	0.3 ± 1	—	0.1 ± 0.3
Agropyron pungens	11	0.3 ± 1	—	0.1 ± 0.3
Polygonum hydropiper	11	0.3 ± 1	—	0.1 ± 0.3
Polygonum sp.	11	0.3 ± 1	—	0.1 ± 0.3

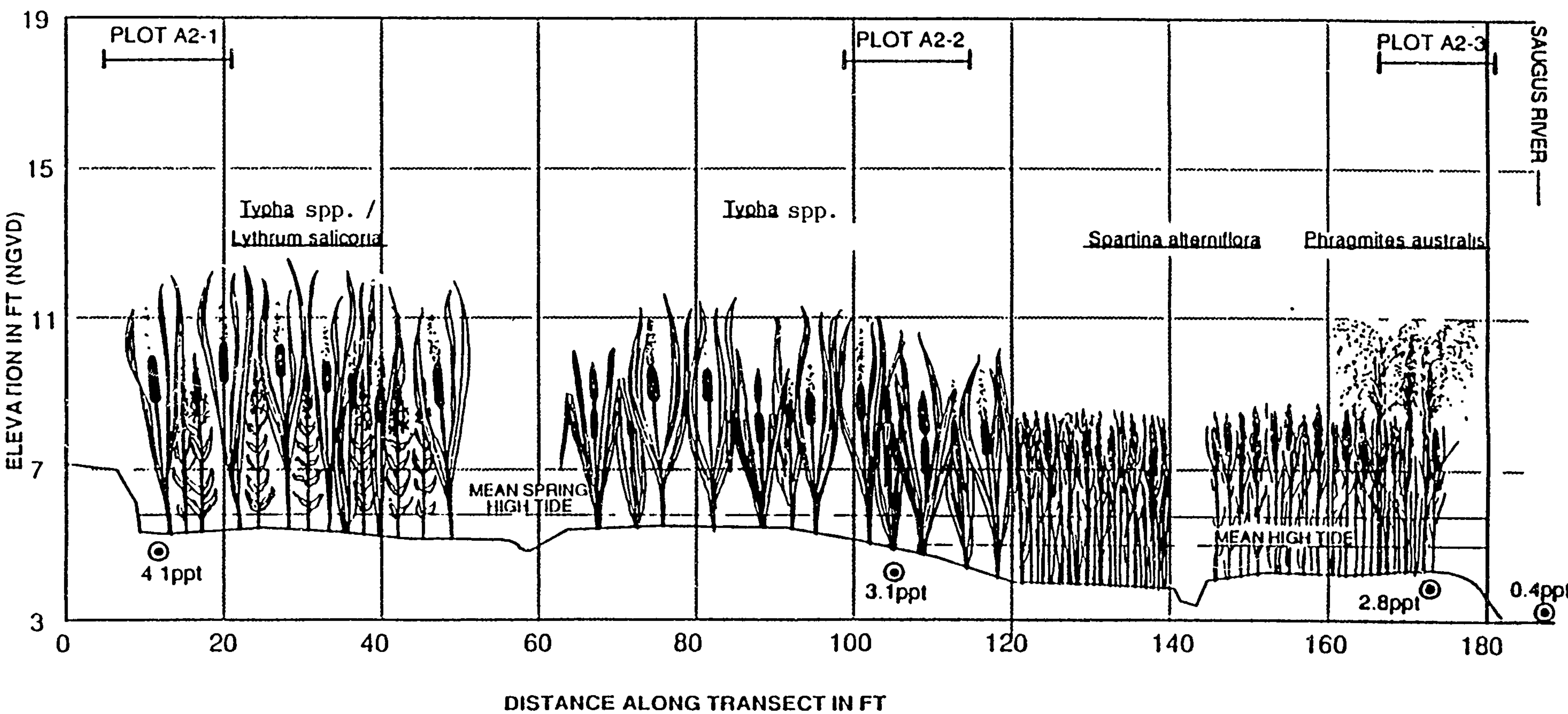
Number of species observed in transect = 14
Number of 1m^2 plots in transect = 9
Mean total percent cover for all plots = 78 ± 16

[1] Percent Frequency of Occurrence = 1m^2 plots in which a species occurs ÷ total number of 1m^2 plots in transect.
[2] Mean Percent Cover = summation of percent cover for each species for all 1m^2 plots in transect ÷ total number of 1m^2 plots in transect.
[3] Mean Height = summation of heights for a species ÷ number of 1m^2 plots in which the species occurs. (No heights were measured for species with less than 5% cover.)
[4] Mean Stem Density = total number of stems of a species along the transect ÷ total number of 1m^2 plots in transect.

Figure K 18

SAUGUS RIVER
TRANSECT NO. A-2
GROUND ELEVATION,
VEGETATION PLOTS
AND SALINITY

⊙ SALINITY READING AT LOW TIDE, 11/11/87



SCALE:
VERT 1" = 4'
HORIZ 1" = 20'

features of the transect. *Phragmites australis* and *Spartina alterniflora* are dominant at the lowest elevations of the marsh (4.0' - 4.3' NGVD), below mean high tide (5.0' NGVD), where they are regularly inundated for short periods. *Typha* spp. dominates at elevations from 4.3' - 5.3'. *Lythrum salicaria* is only present at the upper end of the transect. Interstitial salinities in the downslope end of this transect are slightly lower than in the upslope end, possibly a result of increased freshwater flushing of the marsh adjacent to the river.

Upper Saugus River, Transect A3

Transect A3 was established in the northwest portion of Compartment A, roughly 120m downstream from the Saugus Iron Works (Figure K15). This was the most upstream transect. Three 5m x 5m sample stations were established on the east side of the Saugus River; no stations were located on the west side of the river since it borders directly on a steep upland slope on that side with little wetland vegetation. The transect extended from the wetland/upland boundary at the edge of a shrub-dominated swamp and extended through emergent wetland to the Saugus River. The westernmost plot (A3-3) is only 17m from the central plot to allow the marsh community at the edge of the river to be sampled. A small stream flows through the center of the transect, however no stations were established over the stream.

Phragmites australis is the dominant plant along the transect, occurring in 67% of the $1m^2$ plots with a mean percent cover of 28 (Table K20). *Typha* spp., *Lythrum salicaria* and *Peltandra virginica* (arrow-arum) are also common. The high species richness in the transect (27) is due largely to the presence of the freshwater shrub swamp sampled in plot A3-1, with the more common species within the swamp including *Viburnum recognitum* (northern arrowwood), *Toxicodendron radicans* (poison ivy), *Symplocarpus foetidus* (skunk cabbage) and *Impatiens capensis* (jewelweed). Also, upland tree species overhang the A3-1 plots and are included in the plot data.

Soils along the transect are a mixture of highly decomposed sapric organic and mineral soils. Organic matter content ranges from 5-34% and the mean grain sizes are 41% sand, 27% silt and 10% clay. This transect has the highest percentage of sand and the lowest mean organic matter content (15%) of the three transects in the compartment, perhaps reflecting more alluvial deposition from the inflowing Saugus River. Interstitial salinity readings (range 0.3-0.6 ppt) indicate that the influence of ocean-derived salts is considerably less along this transect than along the other two within this compartment.

Figure K19 shows the cross-section of transect A3 compiled from the surveyed elevation data. There is one narrow ditch present in the center of this transect. A slight ridge is present adjacent to the Saugus River; the ridge has a high percentage of sand, which is likely a result of alluvial deposition. The surface elevation of the vegetated marsh ranges from 4.5' to 5.7' NGVD. Freshwater shrub swamp is present above elevation 5.7' NGVD.

Table K20. **Plant Community Composition Data Along Transect A3, Upper Saugus River**

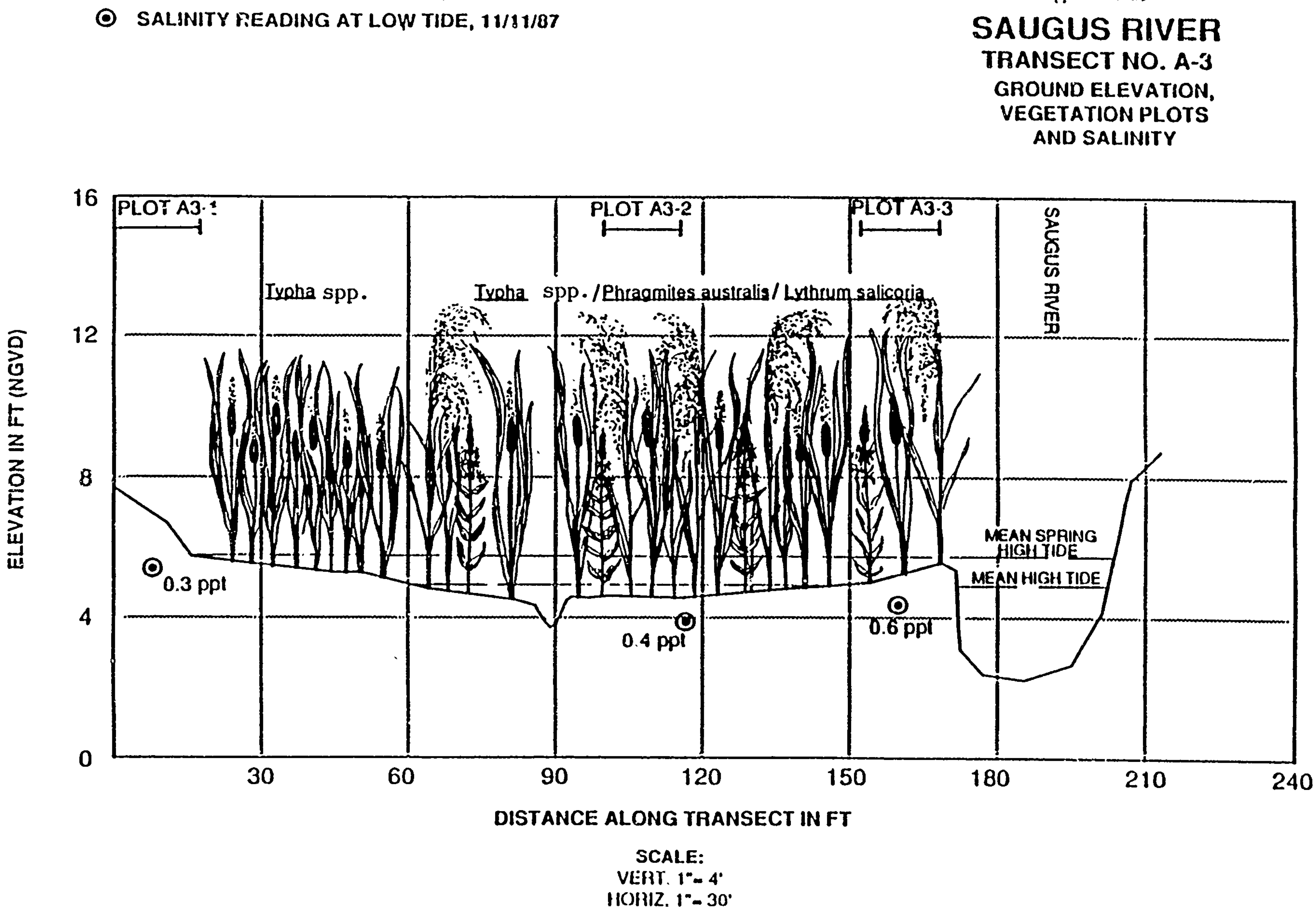
Species	Percent Frequency of Occurrence[1]	Mean Percent Cover (± S.D.)[2]	Mean Height cm (± S.D.)[3]	Mean Stem Density stems/m^2 (± S.D.)[4]
Phragmites australis	67	28 ± 25	270 ± 47	5.0 ± 4.7
Lythrum salicaria	56	12 ± 14	157 ± 63	7.2 ± 11.2
Typha spp.	56	22 ± 24	268 ± 42	14.4 ± 16.9
Peltandra virginica	44	3 ± 6	70 ± 49	0.1 ± 0.3
Acer platanoides	33	28 ± 44	16 meters	0.0
Convolvulus sepium	33	3 ± 7	177 ± 66 (vine)	1.4 ± 2.7
Symplocarpus foetidus	33	1 ± 2	15	0.2 ± 0.4
Prunus serotina	22	12 ± 26	10 meters	0.0
Toxicodendron radicans	22	3 ± 8	73 ± 7	0.0
Impatiens capensis	22	3 ± 7	119 ± 83	0.8 ± 2.3
Carex sp.	22	3 ± 7	55	1.8 ± 5.3
Vitis sp.	22	1 ± 3	35	0.1 ± 0.3
Parthenocissus quinquefolia	22	1 ± 2	28	0.1 ± 0.3
Sium suave	22	1 ± 1	—	0.1 ± 0.3
Viburnum recognitum	11	4 ± 13	186	0.6 ± 2.0
Quercus alba	11	3 ± 10	8 meters	0.0
Cicuta maculata	11	1 ± 3	150	0.2 ± 0.7
Bidens connata	11	1 ± 3	65	0.1 ± 0.3
Myosotis scorpioides	11	1 ± 2	8	1.1 ± 3.3
Acer rubrum	11	0.3 ± 1	—	0.1 ± 0.3
Solanum dulcamara	11	0.3 ± 1	—	0.0
Polygonum hydropiper	11	0.3 ± 1	—	0.2 ± 0.7
Panicum sp.	11	0.3 ± 1	—	0.1 ± 0.3
Chenopodium sp.	11	0.3 ± 1	—	0.1 ± 0.3
Galium sp.	11	0.3 ± 1	—	0.1 ± 0.3
Nasturtium officinale	11	0.3 ± 1	—	0.1 ± 0.3
Cuscuta gronovii	11	0.3 ± 1	—	0.1 ± 0.3

Number of species observed in transect = 27
Number of $1m^2$ plots in transect = 9
Mean total percent cover for all plots = 83 ± 18

[1]Percent Frequency of Occurrence = $1m^2$ plots in which a species occurs ÷ total number of $1m^2$ plots in transect.
[2]Mean Percent Cover = summation of percent cover for each species for all $1m^2$ plots in transect ÷ total number of $1m^2$ plots in transect.
[3]Mean Height = summation of heights for a species ÷ number of $1m^2$ plots in which the species occurs. (No heights were measured for species with less than 5% cover.)
[4]Mean Stem Density = total number of stems of a species along the transect ÷ total number of $1m^2$ plots in transect.

Figure K19

SAUGUS RIVER
TRANSECT NO. A-3
GROUND ELEVATION, VEGETATION PLOTS AND SALINITY



Shute Brook, Transect C

The transect established in Compartment C crosses Shute Brook just north of the Riverside Cemetery in Saugus (Figure K15). The transect contains only two 5m x 5m sample stations, one on each side of Shute Brook, because the band of vegetated wetland bordering the brook is very narrow. The emergent wetland is strongly dominated by Typha spp. which on average covers 75% of the transect (Table K21). Other species, notably Lythrum salicaria, Convolvulus sepium and Phr mites australis, comprise relatively little of the cover. Overall vegetative cover (77%), however, remains within the range observed in Compartment A.

Soils along the transect consist of thin sapric organics, with mean organic matter content of 24% and a range of 11-37%. Mean grain sizes of the soils are 27% sand, 39% silt and 19% clay. Interstitial and open water (in Shute Brook) salinities during low tide ranged from 1.2-1.6 ppt.

Figure K20 shows the topographic cross-section of Transect C across Shute Brook. Shute Brook appears to have been rechannelized at some time in the past for cemetery construction. The present banks of the Brook are 1-2 feet high, rising to the narrow, gently sloping bordering emergent wetlands. The marsh is mostly above mean high tide and is therefore only flooded during tides exceeding mean high tide. The adjacent fill slopes rise steeply for 4-6 feet above the wetlands.

Summary of Upper Saugus River and Shute Brook Data

The percent frequency of occurrence was calculated for each of the 52 species identified in the 39 $1m^2$ plant plots along the 4 transects established in compartments A and C (Table K22). Typha spp., the most abundant plant, has a percent frequency of occurrence of 82 and a range of mean cover along the 4 transects of 22-75%. Lythrum salicaria and Phragmites australis are the next most common species, with frequencies of occurrence in the 39 plots of 36% and 28%, respectively.

A generalized description of the marsh profile at this site from the river channel to upland would consist of a relatively broad zone of cattails (Typha spp.) bordering the river, then a mixed zone near the upland edge of cattails, purple loosestrife (Lythrum salicaria) and common reed (Phragmites australis). This profile was not evident along all transects.

The data obtained on plant species composition, salinity, and elevation within the upper Saugus River and Shute Brook correlate well with a typical description of zonation in tidal freshwater/brackish marshes. Compartment A along the Saugus River, in particular, demonstrates a fairly abrupt change in vegetation composition which correlates well with the salinity and elevation data obtained for this study. While the majority of the species are typically considered freshwater hydrophytes, many of the more common species are known to occur into oligohaline ranges (0.5-5 ppt), with the most abundant species (Typha spp., Phragmites australis) capable of extending into mesohaline ranges (5.0-18 ppt) (Odum et al., 1984).

Table K21. **Plant Community Composition Data Along Transect C, Shute Brook**

Species	Percent Frequency of Occurrence[1]	Mean Percent Cover (± S.D.)[2]	Mean Height cm (± S.D.)[3]	Mean Stem Density stems/m² (± S.D.)[4]
Typha spp.	100	75 ± 8	240 ± 20	42.8 ± 16.0
Convolvulus sepium	83	9 ± 11	130 ± 14	1.2 ± 0.8
Lythrum salicaria	33	1 ± 2	149	0.2 ± 0.4
Phragmites australis	17	2 ± 4	301	1.0 ± 2.4
Armoracia lapathifolia	17	2 ± 4	132	0.6 ± 1.6
Helianthus tuberosus	17	2 ± 4	192	0.5 ± 1.2
Verbena hastata	17	1 ± 2	175	0.0
Polygonum hydropiper	17	1 ± 1	—	0.2 ± 0.4
Parthenocissus quinquefolia	17	1 ± 1	—	0.2 ± 0.4
Rumex sp.	17	1 ± 1	—	0.2 ± 0.4
Artemesia beinnis	17	1 ± 1	—	0.2 ± 0.4
Aster sp.	17	1 ± 1	—	0.0

Number of species observed in transect = 12
Number of $1m^2$ plots in transect = 6
Mean total percent cover for all plots = 77 ± 5

[1] Percent Frequency of Occurrence = $1m^2$ plots in which a species occurs ÷ total number of $1m^2$ plots in transect.
[2] Mean Percent Cover = summation of percent cover for each species for all $1m^2$ plots in transect ÷ total number of $1m^2$ plots in transect.
[3] Mean Height = summation of heights for a species ÷ number of $1m^2$ plots in which the species occurs. (No heights were measured for species with less than 5% cover.)
[4] Mean Stem Density = total number of stems of a species along the transect ÷ total number of $1m^2$ plots in transect.

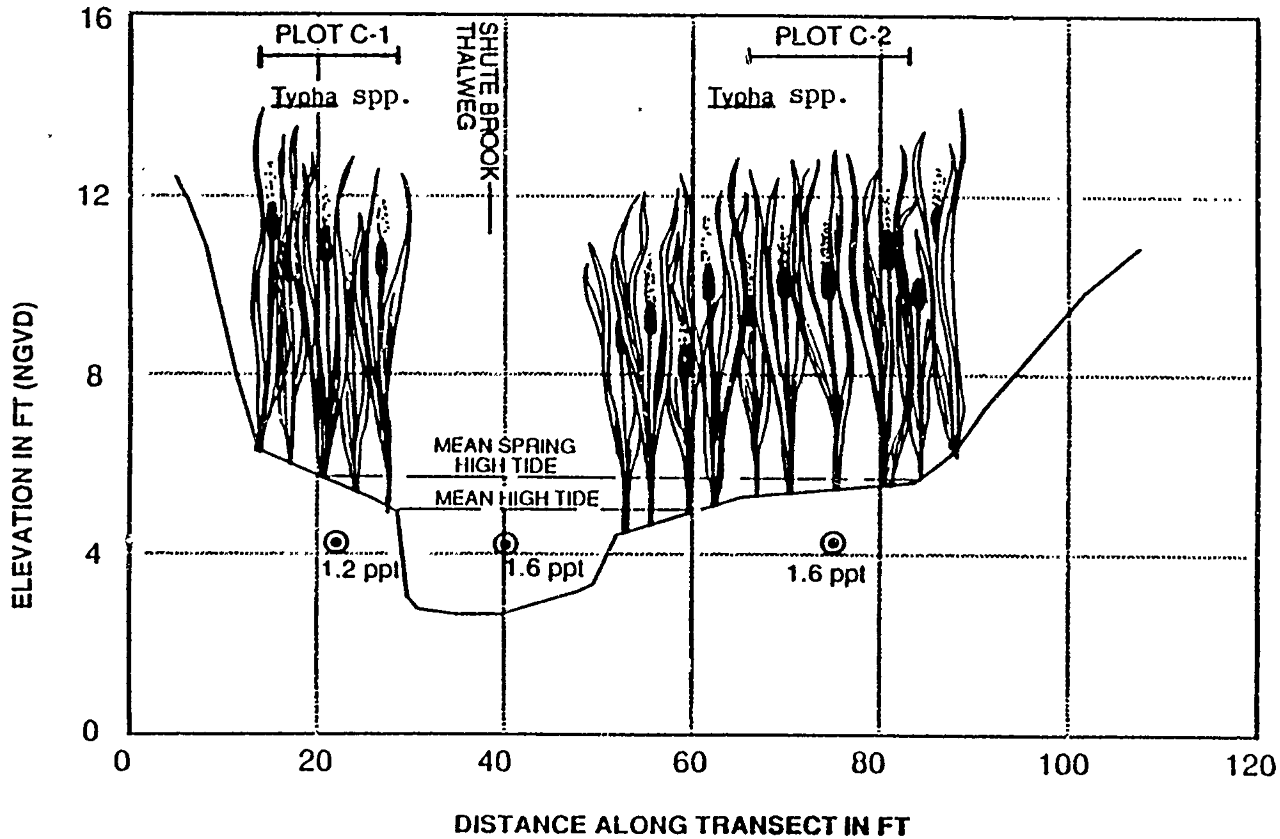
Figure K20

SHUTE BROOK

TRANSECT NO. C-1

GROUND ELEVATION, VEGETATION PLOTS AND SALINITY

SALINITY READING AT LOW TIDE, 11/11/87



SCALE:
VERT. 1"= 4'
HORIZ. 1"= 20'

Table K22. **Summary of Percent Frequency of Occurrence of Species Present in the Upper Saugus River and Shute Brook Transects**

Species	Percent Frequency of Occurrence[1]
Typha spp.	82
Lythrum salicaria	36
Phragmites australis	28
Convolvulus sepium	23
Polygonum hydropiper	18
Spartina alterniflora	15
Peltandra virginica	13
Toxicodendron radicans	8
Symplocarpus foetidus	8
Acer platanoides	8
Parthenocissus quinquefolia	8
Solanum dulcamara	5
Artemesia biennis	5
Scirpus robustus	5
Armoracia lapathifolia	5
Impatiens capensis	5
Vitis sp.	5
Prunus serotina	5
Sium suave	5
Carex sp. 2	5
Unidentified herb	5
Unidentified grass	5
Phalaris arundinacea	3
Myrica gale	3
Lycopus americanus	3
Carex stricta	3
Euthamia tenuifolia	3
Atriplex patula	3
Agropyron pungens	3
Viburnum recognitum	3
Quercus alba	3
Acer rubrum	3
Cicuta maculata	3
Bidens connata	3
Myosotis scorpioides	3
Nasturtium officinale	3
Cuscuta gronovii	3

Table K22. Summary of Percent Frequency of Occurrence of Species Present in the Upper Saugus River and Shute Brook Transects

(Continued)

Species	Percent Frequency of Occurrence[1]
Verbena hastata	3
Helianthus tuberosus	3
Unidentified *Compositae*	3
Solidago sp.	3
Sparganium sp.	3
Carex sp. 1	3
Polygonum sp.	3
Amelanchier sp.	3
Panicum sp.	3
Chenopodium sp.	3
Galium sp.	3
Rumex sp.	3
Aster sp.	3

Total number of $1m^2$ plots on Upper Saugus River and Shute Brook = 39

[1]Percent frequency of occurrence = number of $1m^2$ plots in which a species occurs ÷ total number of $1m^2$ plots.

These figures fit well with the salinity and conductivity data obtained on November 11, 1987 during low tide along the three transects within Compartment A, as well as along the Shute Brook transect (Table K23). There is an obvious decrease in interstitial salinity from transect A2 (furthest downstream) to transect A3 (furthest upstream), although the two transects are within 300 meters of each other. No obvious trends were noted for salinity from the river channel toward the upland.

A summary of the soil analyses for the four Upper Saugus River and Shute Brook transects is provided in Table K24. Most of the soil samples analyzed from these transects are highly decomposed sapric organics. Organic matter content and percent moisture decreased moving upstream and increased from the channel to upland. Some of the samples, such as along transect A3 (furthest upstream), are technically mineral soils based on the lower percentage of organic matter content.

Table K25 presents data for the principal plant species present in each of the 12 5m x 5m plots in the upper estuary, dominated by herbaceous emergents, and provides the elevation and soil data for each plot as well. The majority of the spot elevations in this portion of the marsh fall between 4.0' and 5.5' (NGVD); with a mean high tide level of 5.0', elevation differences within the tidal range (4-5.5') may be an important factor influencing plant zonation. If, however, the salinity levels are within tolerable ranges for the dominant species (which they appear to be), then flooding differences may not be a critical factor in this stretch of the estuary. In particular, _Typha_ spp. dominates most of the plots inventoried, and clearly has the ability to tolerate the ranges in both hydroperiod and salinity which occur in this portion of the marsh.

I. Benthic Habitats

General

The Saugus and Pines Rivers flow through the approximately 1660 acre Saugus and Pines Rivers Estuary before entering Broad Sound and support approximately 239 acres of subtidal habitat and 330 acres of intertidal flat habitat. Additional tidal flats fringe the Lynn and Revere shorefront.

It is generally recognized that tidal flats are an important component of the estuarine environment and are physically and biologically linked to other coastal marine systems (Whitlatch, 1982). Organisms inhabiting tidal flats rely upon organic materials (e.g. plankton, detritus) transported from adjacent salt marsh, coastal and riverine habitats. The abundant and diverse populations of invertebrates and vertebrates that utilize the tidal flats as nursery and feeding grounds are indicative of the high productivity of tidal flats. In addition, many tidal flats, such as the ones in the Study Area, support populations of commercially and recreationally important shellfish and marine worms.

The Lynn-Saugus Harbor area, including Revere, the Saugus River and Pines River contain productive soft shell clam and blue mussel habitat (USACE, 1986; USACE, 1985 a,b). Qualitative observations on the productivity of the

Table K23. Salinity and Conductivity Data for Upper Saugus River and Shute Brook

Transect	Plot	Salinity (ppt)	Conductivity (umhos)	$T^{o}C$	Time of Sampling
A1 (Saugus R.)	A1-1	1.8	1600	6.0	9:30 am
	A1-2	2.2	2130	7.7	9:40 am
	A1-3	1.4	1290	6.6	10:25 am
	A1-4	2.0	750	6.0	10:35 am
	A1-5	0.3	237	7.0	10:40 am
A2 (Saugus R.)	A2-1	4.1	3590	7.0	8:30 am
	A2-2	3.1	3110	7.0	8:40 am
	A2-3	2.8	2780	8.5	8:45 am
	Saugus River Open Water	0.4	520	4.8	8:50 am
A3 (Saugus R.)	A3-1	0.3	193	5.5	11:15 am
	A3-2	0.4	372	7.0	11:20 am
	A3-3	0.6	450	7.6	11:25 am
C (Shute Bk.)	C-1	1.2	1240	7.0	12:15 pm
	C-2	1.6	1650	7.3	12:30 pm
	Shute Brook Open Water	1.6	1700	5.8	12:40 pm

Date of Sampling: November 11, 1987 - low tide at 9:23 am
high tide at 2:55 pm

Table K24. Summary of Soil Analyses for the Upper Saugus River and Shute Brook Transects

Transect	% Moisture	% Organic Matter	% Digestible Matter	% Undigestible Matter	% Sand	% Silt	% Clay
A1 mean ± S.D.	66 ± 11	31 ± 16	---	4.3 ± 2.3	18.4 ± 8.3	45.4 ± 11.5	21.6 ± 5.5
range	52 - 76	11 - 47	---	0.8 - 6.8	9.7 - 30.2	32.6 ± 61.4	12.8 - 26.0
A2 mean ± S.D.	73 ± 13	41 ± 23	---	3.4 ± 0.5	19.6 ± 5.8	41.0 ± 5.1	23.5 ± 6.3
range	58 - 82	15 - 59	---	3.0 - 4.0	13.0 - 23.7	35.1 - 44.1	16.2 - 27.2
A3 mean ± S.D.	51 ± 18	15 ± 17	---	12.3 ± 6.7	41.3 ± 13.0	26.7 ± 1.5	9.8 ± 6.3
range	35 - 71	5.3 - 34	---	5.0 - 18.0	26.3 - 49.6	25.2 - 28.2	3.7 - 16.3
C1 mean ± S.D.	57 ± 23	24 ± 18	---	7.4 ± 0.7	27.1 ± 9.4	39.2 ± 5.9	18.5 ± 1.8
range	40 - 73	11 - 37	---	6.9 - 7.9	20.4 - 33.7	35.0 - 43.4	17.2 - 19.8
A and C							
mean ± S.D.	63 ± 16	28 ± 18	---	6.4 ± 4.7	25.3 ± 12.5	45.5 ± 11.5	21.6 ± 5.5
range	35 - 82	4.2 - 59	---	0.8 - 18	9.7 - 30.2	32.6 - 61.4	12.8 - 26.0

Table K25. Data for Principal Plant Species Relative to Elevation and Soil Data Along Upper Saugus River and Shute Brook Transects

PLOT	ELEVATION	SOIL DATA (%)'				VEGETATION DATA			
		Organic	Sand	Silt	Clay	Species	Average Stems/m^2	Average % Cover	Maximum Height (cm)
A1-1	4.6	37	9.7	52.4	24.6	Typha spp.	49.7	73.3	252
						L. salicaria	0.7	<5.0	—
A1-2	4.2	11	30.2	41.8	12.8	Typha spp.	32.3	54.6	247
						L. salicaria	0.3	5.0	141
						P. arundinacea	15.7	6.7	104
A1-3	4.0	18	11.5	61.4	19.8	Typha spp.	64.3	78.3	235
						S. alterniflora	2.0	3.3	194
A1-4	4.7	42	18.2	38.8	24.9	Typha spp.	33.3	60.0	210
						L. salicaria	0.3	<0.5	—
						T. radicans	11.7	20.0	45
A1-5	5.4	47	22.2	32.6	26.0	Typha spp.	25.3	46.7	212
						Phragmites	7.3	21.7	280
						L. salicaria	4.0	8.3	142
A2-1	7.0-5.3	59	22.0	35.1	27.2	Typha spp.	26.0	61.6	237
						S. robustus	1.7	<5.0	144
						L. salicaria	3.7	13.3	186
A2-2	5.0-3.9	49	13.0	43.8	27.0	Typha spp.	34.0	68.3	196
						S. alterniflora	1.3	1.7	138
A2-3	4.3	15	23.7	44.1	16.2	S. alterniflora	83.7	43.3	177
						Phragmites	24.3	43.3	211
						S. validus	16.6	17.7	148
A3-2	4.5	4.2	49.6	28.2	9.5	Typha spp.	34.0	48.3	290
						Phragmites	8.0	41.7	292
						L. salicaria	20.0	28.3	189
A3-3	5.1-5.5	5.3	48.1	25.2	3.7	Typha spp.	9.3	16.7	300
						Phragmites	7.0	41.7	248
						L. salicaria	1.7	8.3	108
C-1	6.2-4.9	37	20.4	43.4	19.8	Typha spp.	44.3	78.3	267
						Phragmites	2.0	3.3	301
						L. salicaria	0.3	<5.0	--
C-2	5.3-5.6	11	33.7	35.0	17.2	Typha spp.	41.3	71.7	241

soft shell clam (Mya arenaria) habitat in the Saugus/Pines Rivers Estuary have recently been made (HMM Associates, 1986; USFWS, 1984, 1985). Quantitative sampling has been conducted by the Corps of Engineers. The tidal flats of the Saugus River have abundant populations of soft shell clams. High densities of soft shell clams are also thought to occur along the entire length of the Pines River from the confluence upstream to the Sea Plane Basin. Blue mussels (Mytilus edulis) form bars on the gravel-cobble substrate areas of the Pines River, and are extremely abundant in the intertidal flats of Lynn Harbor.

Historical Conditions

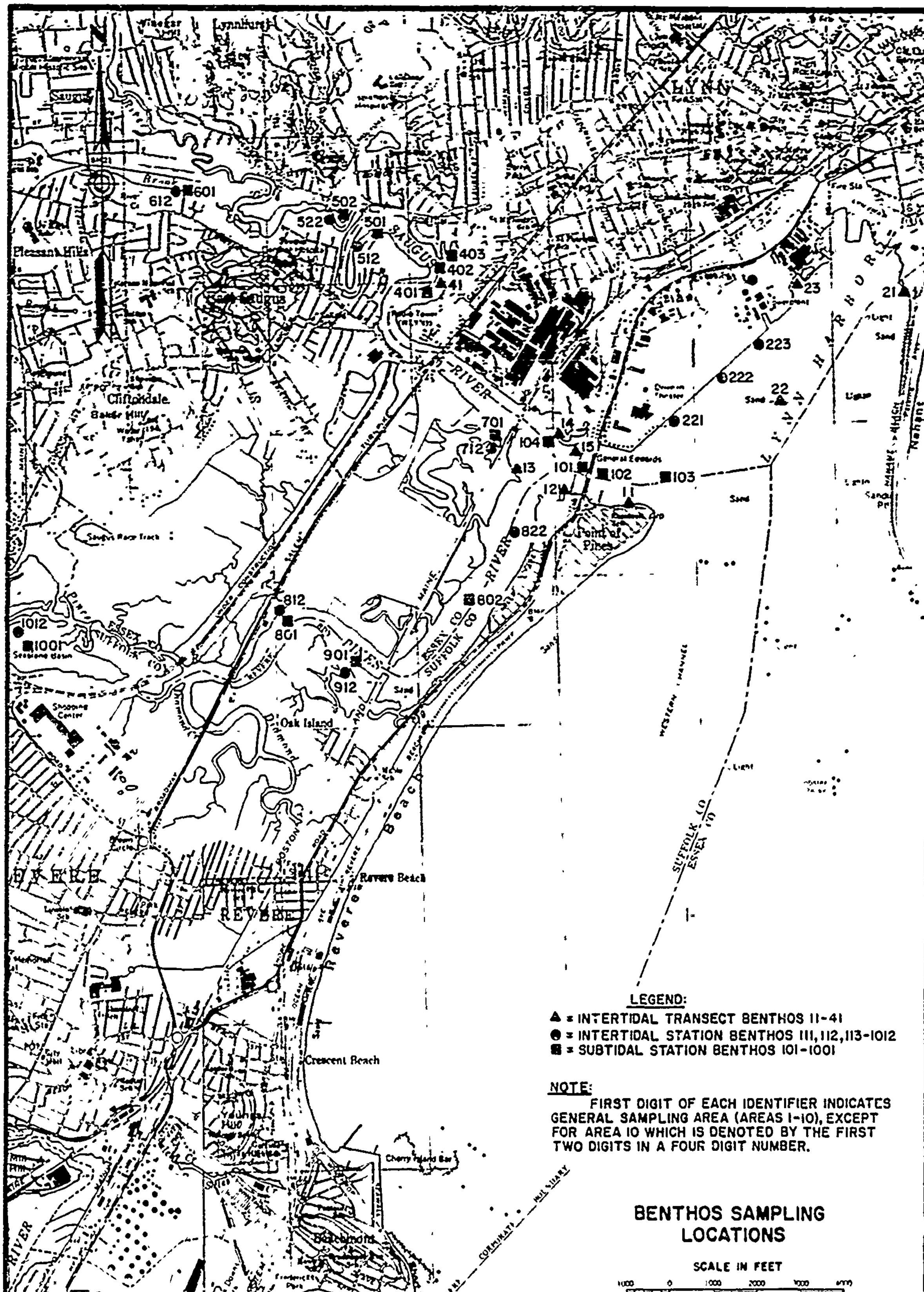
Development over the last 100 years has resulted in losses of saltmarsh habitat, intertidal mudflats and subtidal habitat in the Study Area.

The tidal flats of the Saugus and Pines Rivers Estuary were the primary source of soft shell clams in the early twentieth century, but increasing pollution resulted in harvest restrictions in most of the area by 1926. At the present time, only Master Diggers and their employees may harvest the shellfish beds in the Saugus and Pines Rivers, with the shellfish then requiring depuration at the shellfish purification plant in Newburyport.

Previous studies conducted on the benthic fauna in the Study Area include a survey of the area by Chesmore et al. (1972), and environmental assessments conducted by the Corps of Engineers for the proposed Revere Beach erosion control and Saugus and Pines River Navigation improvement projects. Chesmore et al. (1972) discovered that soft shell clams (Mya arenaria), blue mussels (Mytilus edulis), duck clams (Macoma balthica), tellin shell (Tellina sp.), northern moonsnail (Polinices heros), clam worm (Nereis virens), blood worm (Glycera branchiata) and the ribbon worm (Cerebratulus lacteus) were present in the area. Benthic studies conducted by the Corps of Engineers indicated that the Lynn-Saugus Harbor area, including Revere Beach the Saugus and Pines Rivers, contain productive marine worm and soft shell clam habitat (USACE, 1986, USACE, 1985a,b).

Existing Conditions

As part of the plan formulation process for the Saugus River and Tributaries, Flood Damage Reduction Study, the Corps of Engineers initiated an environmental reconnaissance study (HMM Associates, 1986). Based on the results of this report, ten general areas in the Saugus and Pines Rivers Estuary were identified for further study on the basis of the potential impacts of the regional plan (floodgate) and local protection project options. Sampling took place in 1987 by IEP, Inc. under contract to the Corps. Figure K21 shows the ten general areas where sampling took place. As most of the impacts of the preferred plan are likely to be greatest in the immediate area of the floodgates, the confluence of the Saugus and Pines Rivers was sampled heavily (Area 1). Samples were also taken in Lynn Harbor (Area 2). Saugus River samples included the CSO discharge site (Area 4), the upper Saugus River (Area 5), a small tributary of the Saugus River known as Shute Brook (Area 6) and a marsh site (Area 7). Samples in the Pines River included a sand bar and mudflat (Area 8), a marsh site (Area 9) and the Sea Plane Basin (Area 10). Both subtidal and intertidal areas were sampled to determine species



BENTHOS SAMPLING LOCATIONS

FIGURE K21

composition, mean number of taxa, mean abundance and biomass. In addition, shellfish censuses were done in the intertidal area. Table K26 describes the sampling locations in detail.

Subtidal habitats

The baseline survey for subtidal infauna was conducted in eight of the areas discussed above (Areas 1,4,5,6,7,8,9,10). Replicate samples were taken at each station using a 0.04 m^2 Van Veen Grab.

Species composition was generally similar among all subtidal stations (Table K27). The five dominant taxa at subtidal stations were Oligochaete spp., Capitella spp., Streblospio benedicti, Polydora ligni and Nereis spp. This is not surprising as qualitative evaluation of substrate types among stations indicate that most of the subtidal stations have fairly similar sediment facies. Most of the material consists of sandy-silt or silty sand (Table K28).

There were differences in mean abundance and mean number of taxa among subtidal stations (Table K29). The mean abundance varied from 2990 organisms per square meter at the confluence of the two rivers to 57,600/m^2 at the Pines River marsh site. Mean number of taxa varied from 10 at the Shute Brook site to 26/station at the Pines River marsh site. These differences can be attributed to differences in the physical location of the stations.

There was a general trend toward increased abundance and decreased number of taxa as one moves from the mouth of the Saugus River (Area 1) to the upper reaches of the Saugus River (Area 5 and Area 6) (Table K29). This corresponds with a slight trend from estuarine to riverine conditions in temperature, conductivity and dissolved oxygen in the Saugus River. Lowest temperatures were recorded near the mouth of the river (Area 1) and highest temperatures were recorded upriver (Areas 5 and 6) (See Table K28). Shute Brook (Area 6) had the lowest conductivity value, suggesting a predominance of freshwater inflow. Dissolved oxygen decreased upriver from 8.6 mg/l (Area 1) to 5.0 mg/l (Area 5).

No upriver trends in oxygen, conductivity or temperature were evident in the three stations located in the Pines River, suggesting the water in this area is fairly well mixed. Correspondingly, no upriver trends were noted in abundance or number of taxa for the Pines River.

The highest mean abundances of all subtidal stations occurred at the marsh stations (Areas 7 and 9). Both of these areas are characterized by restricted water circulation and high deposition rates. The polychaete Streblospio benedicti dominated at both stations and represented over 60 percent of the fauna at these stations. This species is typical of organically enriched areas (Pearson and Rosenburg, 1978).

In general, the similarity in composition of dominant taxa at each subtidal station within a given area suggests that habitat characteristics within a given area are similar. Differences among stations can generally be attributed to differences in sediment types or water quality (as in Shute

Table K26. Station and Transect Location Descriptions with the Number and Type of Samples Collected at Subtidal and Intertidal Benthic Stations.

AREA/NUMBER		STATIONS/TRANSECT LOCATION	SAMPLES
1 Tidegate Site	Subtidal 101 Stations	Approximately midway between General Edwards Bridge and overhead pipeline on the northerly shore of Saugus River	4 stations x 3 grabs = 12 grabs
	102	50 yds seaward of northerly end of General Edwards Bridge, opposite the fifth bridge abutment from the north shoreline	
	103	Approximately 100 yds north of Buoy R"10"	
	104	Saugus River channel, west of the General Edwards Bridge under transmission lines	
Intertidal	Transects 11	Point of Pines across from MDC fish pier; approximately 200 ft seaward	5 transects x 3 stations x 3 replicates = 45 cores 5 transects x 3 stations x 3 replicates = 45 shellfish grids
	12	South shore of Saugus River; approximately 150 yds west of General Edwards Yacht Club	
	13	West bank of confluence of Pines and Saugus Rivers; approximately 50 ft. NE of old bridge	Stations: 111, 112, 113, 121, 122, 123, 131, 132, 133, 141, 142, 143, 151, 152, & 153
	14	North shore of Saugus River; approximately 125 yds north of overhead transmission lines	
	15	North shore of Saugus River; approximately 100 yds southeast of overhead transmission lines	

Table K26 (Continued)

AREA/NUMBER		STATIONS/TRANSECT LOCATION	SAMPLES
2 Lynn Harbor Site	Intertidal Transects 21 (Nahant Beach Parkway)	Stations 211, 212, and 213; east shore of Lynn Harbor; approximately 100 ft. southerly from the MDC Public Boat Ramp	1 transect x 3 stations x 3 replicates = 9 cores 1 transect x 3 stations x 3 replicates = 9 shellfish grids Stations: 211, 212 & 213
	22 (Lynn Harbor)	Station 221; approximately 400 yds NE of SE end of Lynn Harbor bulkhead; approximately 25 ft. from the bulkhead itself	1 transect x 3 stations x 3 replicates = 9 cores 1 transect x 3 stations x 3 replicates = 9 shellfish grids Stations: 221, 222 & 223
		Station 222; approximately 850 yds from SE end of Lynn Harbor bulkhead; approximately 50 ft. from the bulkhead itself	
		Station 223; approximately 1300 yds from SE end of Lynn Harbor bulkhead; approximately 50 ft. from the shoreline	
	23 (Dike area)	Stations 231, 232, and 233; NE side of Lynn Harbor; approximately 50 ft. NE of the rip-rap bordering Lynn Public Boat Ramp parking lot	1 transect x 3 stations x 3 replicates = 9 cores 1 transect x 3 stations x 3 replicates = 9 shellfish grids Stations: 231, 232, & 233
4 Saugus River CSO Discharge Site	Intertidal Transect 41	CSO on north side of Saugus River below GE parking area; approximately 100 yds north of junk yard	1 transect x 3 stations x 3 replicates = 9 cores 1 transect x 3 stations x 3 replicates = 9 shellfish grids Stations: 411, 412 & 413
	Subtidal 401 Stations	Within Saugus River channel, approximately 100 yds seaward from Station 412	3 stations x 3 grabs = 9 grabs

Table K26 (Continued)

AREA/NUMBER			STATIONS/TRANSECT LOCATION	SAMPLES
		402	Within Saugus River channel, seaward of the inlet before the CSO	
		403	Mid-stream approximately 50 yds into inlet leading to CSO	
5 Upper Saugus River	Intertidal Stations	512	500 ft. NE tip of island in Saugus River, upstream of Saugus Yacht Club	2 stations x 4 replicates = 8 cores 2 stations x 4 replicates = 8 shellfish grids
		522	Approximately 100 yds downstream of Lincoln Avenue bridge, south side of Saugus River	
	Subtidal Stations	501	Midstream on south side of island in Saugus River; approximately 25 yds south of fork in river	2 stations x 4 replicates = 8 grabs
		502	Approximately 100 yds downstream of Lincoln Avenue bridge; southerly side of mid-stream of Saugus River	
6 Shute Brook Site	Intertidal Station	612	Approximately 150 yds downstream from SE end of Riverside Cemetery	1 station x 4 replicates = 4 cores 1 station x 4 replicates = 4 shellfish grids
	Subtidal Station	602	Midstream, approximately 150 yds downstream from SE corner of Riverside Cemetery	1 station x 4 replicates = 4 grabs
7 Marsh I Site	Intertidal Station	712	South side of Bear Creek, approximately 200 yds upstream from confluence with Saugus River	1 station x 3 replicates = 3 cores 1 station x 3 replicates = 3 shellfish grids
	Subtidal Station	702	South side of Bear Creek in mid-channel on east side of small inlet approximately 150 yds upstream from confluence with Saugus River	1 station x 3 replicates = 3 grabs

Table K26 (Continued)

AREA/NUMBER		STATIONS/TRANSECT LOCATION	SAMPLES
8 Pine River Site	Intertidal Stations	812 Midstream sandbar approximately 200 yds upstream from WROL radio tower on Rte 107	2 stations x 3 replicates = 6 cores 2 stations x 3 replicates = 6 shellfish grids
		822 Midstream mudflat approximately 500 yds upstream from confluence with Saugus River	
	Subtidal Stations	801 South side of midstream sandbar, 200 yds upstream of the WROL radio tower	2 stations x 3 replicates = 6 grabs
		802 East side of channel approximately 1000 yds upstream from confluence with Saugus River	
9 Marsh M Site	Intertidal Station	912 West side of small creek, 400 yds upstream of B&M RR bridge, whose confluence is on westerly side of Pines River	1 station x 3 replicates = 3 cores 1 station x 3 replicates = 3 shellfish grids
	Subtidal Station	901 25 yds upstream of small stream entering south side of Pines River, approximately 200 yds upstream of B&M RR bridge	1 station x 3 replicates = 3 grabs
10 Seaplane Basin Site	Intertidal Station	1012 NE side of Basin approximately 500 yds NNE of MDC tide gates below Rte 1	1 station x 3 replicates = 3 cores 1 station x 3 replicates = 3 shellfish grids
	Subtidal Station	1001 NE side of Basin approximately 500 yds NNE of MDC tide gates below Rte 1 within channel	1 station x 3 replicates = 3 grabs

Table K27. NUMERICALLY DOMINANT MACROBENTHIC TAXA COLLECTED AT SUBTIDAL STATIONS

Area Station	Taxon[a]	%	Area Station	Taxon	%	Area Station	Taxon	%
1 101	Capitella capitata	40.8	4 402	Oligochaeta	84.8	7 701	Streblospio benedicti	68.2
	Oligochaeta	31.3		Capitella capitata	6.8		Capitella capitata	14.1
	Streblospio benedicti	11.3		Streblospio benedicti	3.5		Oligochaeta	9.6
	Caulleriella sp B	5.2		Nereis diversicolor	2.6		Polydora ligni	2.3
	Polydora ligni	4.8		Nereis spp.	2.2		Spio setosa	2.0
	Percent of Total	93.4		Percent of Total	99.9		Percent of Total	96.2
	Total No. ind./sta.	230		Total No. ind./sta.	854		Total No. ind./sta.	4,697
102	Oligochaeta	23.6	403	Streblospio benedicti	68.6	8 801	Paraonis fulgens	20.8
	Capitella capitata	22.8		Polydora ligni	9.7		Capitella capitata	20.3
	Polydora ligni	14.9		Oligochaeta	9.5		Caulleriella sp B	18.8
	Aricidea catherinae	13.6		Nereis diversicolor	5.2		Oligochaeta	15.2
	Caulleriella sp B	6.2		Nereis spp.	4.9		Aricidea catherinae	8.0
	Percent of Total	81.1		Percent of Total	97.9		Percent of Total	83.1
	Total No. ind./sta.	390		Total No. ind./sta.	1,995		Total No. ind./sta.	664
103	Polydora ligni	35.8	5 501	Streblospio benedicti	48.8	802	Capitella capitata	33.7
	Capitella capitata	10.0		Oligochaeta	30.2		Oligochaeta	22.2
	Oligochaeta	8.3		Nereis diversicolor	6.7		Aricidea catherinae	20.6
	Aricidea catherinae	6.7		Scolecolepides viridis	5.9		Streblospio benedicti	9.5
	Petricola pholadiformis	6.7		Polydora ligni	2.6		Polydora ligni	3.1
	Percent of Total	67.5		Percent of Total	94.2		Percent of Total	89.1
	Total No. ind./sta.	120		Total No. ind./sta.	744		Total No. ind./sta.	927
104	Oligochaeta	54.0	502	Oligochaeta	56.7	9 901	Streblospio benedicti	62.2
	Capitella capitata	16.7		Streblospio benedicti	27.4		Caulleriella sp B	12.2
	Polydora ligni	8.6		Nereis diversicolor	5.4		Oligochaeta	9.4
	Caprellidae	8.6		Scolecolepides viridis	3.1		Polydora ligni	4.4
	Corophium insidiosum	1.9		Nereis spp.	2.8		Cirratulidae	3.8
	Percent of Total	89.8		Percent of Total	95.4		Percent of Total	92.0
	Total No. ind./sta.	359		Total No. ind./sta.	3,489		Total No. ind./sta.	6,912
4 401	Polydora ligni	30.5	6 601	Oligochaeta	65.8	10 1001	Oligochaeta	44.8
	Oligochaeta	29.5		Hypaniola florida	18.0		Paraonis fulgens	10.8
	Nereis diversicolor	14.7		Cyathura polita	7.6		Capitella capitata	7.2
	Nereis spp.	13.1		Nereis diversicolor	5.7		Gemma gemma	6.5
	Spio setosa	3.7		Ampharetidae	1.6		Aricidea catherinae	6.1
	Percent of Total	91.5		Percent of Total	98.7		Percent of Total	75.4
	Total No. ind./sta.	1,133		Total No. ind./sta.	2,051		Total No. ind./sta.	657

Table K28. SUMMARY OF PHYSICAL DATA AND HYDROGRAPHIC VARIABLES COLLECTED AT SUBTIDAL STATIONS

Area	Station	Grain Size	Presence of:[a]	Bottom Conditions Depth (m)	Secchi (m)	Temp. (C)	Cond. (umho)	D.O. (mg/L)
1	101	Sandy silt with peat	--[b]	4.1	3.5	18.4	39.90	8.6
	102	Sandy silt	AT	3.6	1.7	18.3	39.80	8.5
	103	Silty sand	AT	2.4	1.2	19.2	40.80	8.9
	104	Sandy silt	H_2S	2.7	1.5	18.2	40.00	8.4
	Area 1 Mean (std.dev.)			3.2 (0.8)	2.0 (1.0)	18.5 (0.5)	40.13 (0.46)	8.6 (0.2)
4	401	Sandy silt	--	2.5	0.9	23.5	44.40	7.2
	402	Sandy silt	--	3.0	0.8	24.3	44.20	6.9
	403	Pebbley sand with silt	--	1.3	0.9	24.9	44.00	5.9
	Area 4 Mean (std. dev.)			2.3 (0.9)	0.9 (0.1)	24.2 (0.7)	44.20 (0.2)	6.7
5	501	Peaty silt	--	--	0.9	26.2	42.00	5.5
	502	Peaty silt	--	--	0.2	22.9	37.50	5.0
6	601	Silty sand	--	0.4	--	27.2	32.40	11.6
7	701	Silty clay	--	--	0.8	20.6	42.10	8.3
8	801	Silty sand	--	--	0.6	22.4	43.10	8.2
	802	Clayey silt	--	--	0.6	20.2	42.10	8.4
9	901	Silt	--	--	0.4	25.8	42.00	8.7
10	1001	Sand	--	--	0.4	21.8	43.00	7.4

[a] I = large invertebrate; AL = algae; AT = animal tubes; EG = eelgrass; H_2S = hydrogen sulfide odor.

[b] -- = not reported.

Table K29. SUMMARY OF MEAN ABUNDANCE[a] AND MEAN NUMBER OF TAXA[b] AT SUBTIDAL STATIONS

Station	Area 1	4	5	6	7	8	9	10
ABUNDANCE:	Mean (sd)							
01	76.7 (98.3)	377.7 (95.6)	186.0 (92.6)	512.8 (185.6)	1,559.7 (252.2)	221.3 (43.7)	2,304.0 (2,030.1)	219.0 (26.7)
02	130.0 (36.7)	284.7 (309.0)	872.3 (745.4)			309.0 (33.2)		
03	40.0 (12.0)	665.0 (149.0)						
04	119.7 (76.6)							
Area Mean (sd)	91.6 (67.1)	442.4 (247.4)	529.1 (613.5)	512.8 (185.6)	1,559.7 (252.2)	265.2 (59.2)	2,304.0 (2,030.1)	219.0 (26.7)
NUMBER OF TAXA:	Mean (sd)							
01	13.0 (5.3)	17.0 (1.0)	11.5 (0.6)	10.0 (1.4)	20.3 (1.5)	20.3 (2.1)	25.7 (7.5)	17.3 (1.2)
02	21.0 (1.7)	9.3 (1.2)	12.3 (1.5)			21.3 (3.8)		
03	15.0 (2.7)	11.0 (1.7)						
04	19.3 (1.5)							
Area Mean (sd)	17.1 (4.3)	12.4 (3.7)	11.9 (1.1)	10.0 (1.4)	20.3 (1.5)	20.8 (2.8)	25.7 (7.5)	17.3 (1.2)

[a] Measured as mean number of individuals/0.04m^2.
[b] Measured as mean number of taxa/station.

Brook). The muddy areas were dominated by opportunistic polychaetes; the sandier stations had a more even distribution of organisms (compare Table K28 with Table K27).

Intertidal habitats

Nine areas (Areas 1,2,4,5,6,7,8,9 and 10) were sampled and the fauna collected were compared in terms of mean abundance, mean number of taxa, species composition, and shellfish abundance. Replicate samples were taken using a 1.0 liter (0.01m2) hand core. The survey design for the intertidal areas was based on among area (and station) comparisons, stratified by tidal height (high, mid and low tide levels).

Similar species were dominant at all the intertidal stations (Table K30). Species such as Oligochaeta spp., Capitella spp., Streblospio benedicti, Polydora ligni, Nereis spp. and Pygospio elegans are opportunistic species, which occurred at most of the stations. These taxa tend to be generalists that exhibit wide tolerances for differences in sediment characteristics. Mean abundance and the mean numbers of taxa varied considerably among areas for all tidal heights. Highest densities of individuals and greatest number of taxa were generally observed at mid-tide levels. Comparing the mid-tide levels, mean number of individuals varied om $7,800/m^2$ at the Sea Plane Basin to $161,100/m^2$ at the Pines River marsh site. Mean number of taxa varied from 7 at Shute Brook to 21 at the Pines River Marsh site (Table K31). These results are not unexpected given the wide variety of station locations, exposure regimes (tidal heights) and sediment types both among and within areas (See Table K32). Although grain size distribution of stations within an area varied widely, the grain size tended to be more similar among stations located along an intertidal transect than among stations at the same tidal height. These patterns account for much of the variability observed in mean abundance and mean number of taxa among stations and areas. In general, at a given tidal height, stations with finer sediments were characterized by higher abundance and lower diversity of organisms (compare Table K32 with Tables K31 and K30), while sandier sediments were characterized by decreased abundance and an increased number and more even distribution of taxa.

Shellfish

To evaluate the potential impact of the project on shellfish resources in the Study Area, a shellfish census was conducted. Shellfish were collected at randomly located grids ($0.04m^2$) in approximately the same locations as the intertidal transects and stations. Additional grids were sampled along the Pines River (near Area 8), upper Saugus River (near Area 5) and near the CSO discharge in the Saugus River (near Area 4). The sampling locations may be found on Figure K22. At each location three randomly deployed $0.04m^2$ shellfish grids were excavated to a 20cm depth and sieved for each tide level. The samples were sieved on-site through a 1.0mm sieve. All shellfish were measured (nearest 1.0mm) and enumerated. Table K33 presents a summary of the mean numbers of shellfish collected, by station. Six species of shellfish were collected: Mya arenaria, Macoma balthica, Gemma gemma, Ensis directus,

Table K30. NUMERICALLY DOMINANT MACROBENTHIC TAXA COLLECTED AT INTERTIDAL STATIONS

Area	Transect[a]	Station 1 (High tide) Taxon	%	Station 2 (Mid tide) Taxon	%	Station 3 (Low tide) Taxon	%
1	11	Pygospio elegans	52.2	Pygospio elegans	98.6	Capitella capitata	26.3
		Mytilidae	21.7	Oligochaeta	0.9	Gemma gemma	26.3
		Gemma gemma	13.0	Capitella capitata	0.2	Pygospio elegans	21.0
		Capitella capitata	4.3	Mya arenaria	0.1	Mya arenaria	10.5
		Mya arenaria	4.3	2 spp. w/ 1 ind.		3 spp. w/ 1 ind.	
		Percent of Total	95.5	Percent of Total	100	Percent of Total	84.1
		Total No. ind./sta.	23	Total No. ind./sta.	1,430	Total No. ind./sta.	38
1	12	Capitella capitata	32.9	Capitella capitata	41.9	Oligochaeta	29.6
		Nereis spp.	27.4	Oligochaeta	23.8	Capitella capitata	29.0
		Polydora ligni	16.6	Polydora ligni	8.6	Jaera marina	15.1
		Nereis diversicolor	13.7	Streblospio benedicti	7.2	Streblospio benedicti	7.6
		Oligochaeta	4.4	Pygospio elegans	3.9	Polydora ligni	5.5
		Percent of Total	95.0	Percent of Total	85.4	Percent of Total	86.8
		Total No. ind./sta.	592	Total No. ind./sta.	487	Total No. ind./sta.	1,522
1	13	Oligochaeta	47.3	Streblospio benedicti	56.5	Streblospio benedicti	47.8
		Capitella capitata	24.7	Oligochaeta	21.3	Capitella capitata	15.6
		Streblospio benedicti	12.4	Capitella capitata	9.7	Oligochaeta	13.1
		Corophium volutator	4.8	Corophium volutator	6.4	Corophium volutator	7.7
		Nereis spp.	2.8	Polydora ligni	2.1	Polydora ligni	6.7
		Mya arenaria	2.8				
		Percent of Total	94.8	Percent of Total	96.0	Percent of Total	90.9
		Total No. ind./sta.	970	Total No. ind./sta.	3,005	Total No. ind./sta.	778
1	14	Gemma gemma	86.7	Gemma gemma	21.3	Pygospio elegans	43.1
		Oligochaeta	6.7	Oligochaeta	20.4	Polydora ligni	22.0
		Neomysis americana	6.7	Capitella capitata	16.5	Oligochaeta	18.4
				Streblospio benedicti	11.3	Capitella capitata	12.1
				Nereis spp.	11.2	Nereis spp.	4.0
		Percent of Total	100	Percent of Total	80.7	Percent of Total	99.6
		Total No. ind./sta.	15	Total No. ind./sta.	842	Total No. ind./sta.	223
1	15	Streblospio benedicti	37.1	Oligochaeta	66.5	Streblospio benedicti	44.0
		Oligochaeta	16.0	Streblospio benedicti	19.8	Capitella capitata	32.1
		Pygospio elegans	11.3	Corophium volutator	6.3	Caulleriella sp B	5.2
		Nereis spp.	11.2	Pygospio elegans	2.1	Polydora ligni	4.9
		Corophium volutator	7.3	Capitella capitata	1.4	Oligochaeta	3.3
		Percent of Total	82.9	Percent of Total	96.1	Percent of Total	89.5
		Total No. ind./sta.	904	Total No. ind./sta.	2,047	Total No. ind./sta.	823
2	21	Oligochaeta	96.3	Capitella capitata	42.0	Capitella capitata	45.8
		Caulleriella sp B	3.7	Spio setosa	26.2	Polydora ligni	16.7
				Pygospio elegans	12.3	Streblospio benedicti	16.3
				Polydora ligni	4.6	Spio setosa	13.2
				Oligochaeta	4.3	Pygospio elegans	6.0
		Percent of Total	100.0	Percent of Total	89.4	Percent of Total	98.0
		Total No. ind./sta.	54	Total No. ind./sta.	324	Total No. ind./sta.	251
2	22	Oligochaeta	77.9	Capitella capitata	31.3	Oligochaeta	20.0
		Nereis spp.	7.6	Oligochaeta	27.6	Spiophanes bombyx	20.0
		Nereis diversicolor	5.1	Polydora ligni	7.8	Mytilidae	20.0
		Pygospio elegans	4.4	Nereis diversicolor	7.0	Lumbriculidae	20.0
		Nereis virens	3.8	Nereis spp.	6.6	Glycera capitata	20.0
		Percent of Total	98.8	Percent of Total	80.3	Percent of Total	100
		Total No. ind./sta.	158	Total No. ind./sta.	243	Total No. ind./sta.	5

[a] Transects in parentheses are single stations.

Table K30 (Continued)

Area	Transect	Station 1 (High tide) Taxon	%	Station 2 (Mid tide) Taxon	%	Station 3 (Low tide) Taxon	%
2	23	Streblospio benedicti	29.8	Pygospio elegans	50.2	Capitella capitata	41.4
		Caulleriella sp 8	26.5	Oligochaeta	32.8	Oligochaeta	32.8
		Cirratulidae	14.0	Capitella capitata	9.1	Streblospio benedicti	14.3
		Oligochaeta	11.3	Streblospio benedicti	3.7	Cirratulidae	4.3
		Capitella capitata	4.9	Polydora ligni	1.5	4 spp. w/ ind.	4.3
		Percent of Total	86.5	Percent of Total	97.3	Percent of Total	97.1
		Total No. ind./sta.	1,084	Total No. ind./sta.	876	Total No. ind./sta.	70
4	41	Oligochaeta	89.0	Oligochaeta	47.9	Oligochaeta	67.5
		Streblospio benedicti	9.8	Nereis diversicolor	22.9	Nereis diversicolor	19.2
		Mytilidae	1.2	Nereis spp.	18.3	Polydora ligni	6.1
				Polydora ligni	7.0	Nereis spp.	5.3
				Mya arenaria	1.8	Mya arenaria	1.0
		Percent of Total	100	Percent of Total	97.9	Percent of Total	99.1
		Total No. ind./sta.	82	Total No. ind./sta.	660	Total No. ind./sta.	832
5	(51)			Streblospio benedicti	59.6		
				Oligochaeta	21.7		
				Nereis spp.	9.0		
				Nereis diversicolor	5.4		
				Fabricia sabella	2.2		
				Percent of Total	97.9		
				Total No. ind./sta.	4,043		
5	(52)			Fabricia sabella	33.0		
				Oligochaeta	24.8		
				Polydora ligni	11.5		
				Nereis spp.	11.1		
				Nereis diversicolor	9.8		
				Percent of Total	90.2		
				Total No. ind./sta.	1,256		
6	(61)			Oligochaeta	49.0		
				Fabricia sabella	38.7		
				Nereis spp.	4.1		
				Nereis diversicolor	3.2		
				Ampharetidae	3.0		
				Percent of Total	98.0		
				Total No. ind./sta.	1,112		
7	(71)			Streblospio benedicti	63.0		
				Oligochaeta	24.6		
				Capitella capitata	4.3		
				Polydora ligni	2.8		
				Nereis spp.	1.4		
				Percent of Total	96.1		
				Total No. ind./sta.	2,726		
8	(81)			Capitella capitata	28.3		
				Streblospio benedicti	20.0		
				Oligochaeta	14.0		
				Pygospio elegans	13.8		
				Polydora ligni	8.6		
				Percent of Total	84.7		
				Total No. ind./sta.	385		

Table K30 (Continued)

Area	Transect	Station 1 (High tide) Taxon	%	Station 2 (Mid tide) Taxon	%	Station 3 (Low tide) Taxon	%
8	(82)			*Capitella capitata*	19.9		
				Jaera marina	18.4		
				Oligochaeta	15.3		
				Semibalanus balanoides	15.1		
				Polydora ligni	14.6		
				Percent of Total	83.3		
				Total No. ind./sta.	1,937		
9	(91)			*Streblospio benedicti*	83.3		
				Oligochaeta	6.3		
				Polydora ligni	2.7		
				Capitella capitata	2.6		
				Cirratulidae	2.0		
				Percent of Total	96.9		
				Total No. ind./sta.	4,832		
10	(101)			*Nereis* spp.	23.0		
				Oligochaeta	16.6		
				Gemma gemma	13.6		
				Nereis diversicolor	13.2		
				Streblospio benedicti	9.8		
				Percent of Total	76.2		
				Total No. ind./sta.	235		

Table K31. SUMMARY OF MEAN ABUNDANCE[a] AND MEAN NUMBER OF TAXA[b] AT INTERTIDAL STATIONS

		Tidal Level					
		Station 1 (High)		Station 2 (Mid)		Station 3 (Low)	
		Mean (sd)		Mean (sd)		Mean (sd)	
Area	Transect[c]	Abundance	No. of Taxa	Abundance	No. of Taxa	Abundance	No. of Taxa
1	11	7.7 (4.7)	7.0 (3.0)	476.7 (213.5)	7.0 (2.7)	12.7 (4.5)	9.0 (1.7)
1	12	197.3 (26.5)	16.0 (1.0)	162.3 (135.7)	14.7 (7.6)	507.3 (200.0)	29.7 (2.1)
1	13	323.3 (145.9)	19.3 (1.5)	1,001.7 (30.0)	18.3 (3.2)	259.3 (222.9)	15.3 (7.0)
1	14	5.0 (3.6)	3.0 (1.0)	280.7 (56.1)	16.7 (5.7)	74.3 (21.8)	8.0 (1.0)
1	15	301.3 (253.7)	10.0 (6.1)	682.3 (79.4)	13.3 (2.9)	274.3 (113.4)	19.0 (1.0)
2	21	18.0 (10.6)	2.7 (1.2)	108.0 (46.4)	14.0 (1.0)	83.7 (18.7)	8.3 (1.5)
2	22	52.7 (13.6)	10.0 (1.7)	81.0 (12.5)	12.0 (2.0)	1.7 (1.5)	2.0 (1.0)
2	23	361.3 (55.5)	13.0 (0)	292.0 (107.5)	10.7 (1.2)	23.3 (9.0)	4.7 (1.5)
4	41	27.3 (31.8)	2.0 (1.0)	220.0 (78.0)	10.0 (3.0)	277.3 (28.7)	12.3 (2.3)
5	(51)			1,010.8 (124.4)	12.3 (2.6)		
5	(52)			314.0 (55.6)	9.3 (0.5)		
6	(61)			278.0 (116.5)	7.0 (0.8)		
7	(71)			908.7 (284.7)	17.3 (3.5)		
8	(81)			128.3 (27.2)	15.7 (2.5)		
8	(82)			545.7 (283.3)	19.7 (2.9)		
9	(91)			1,610.7 (758.4)	21.3 (0.6)		
10	(101)			78.3 (22.8)	14.7 (2.1)		

[a] Measured as mean number of individuals/0.01m^2.
[b] Measured as mean number of taxa/station.
[c] Transects in parentheses are single stations.

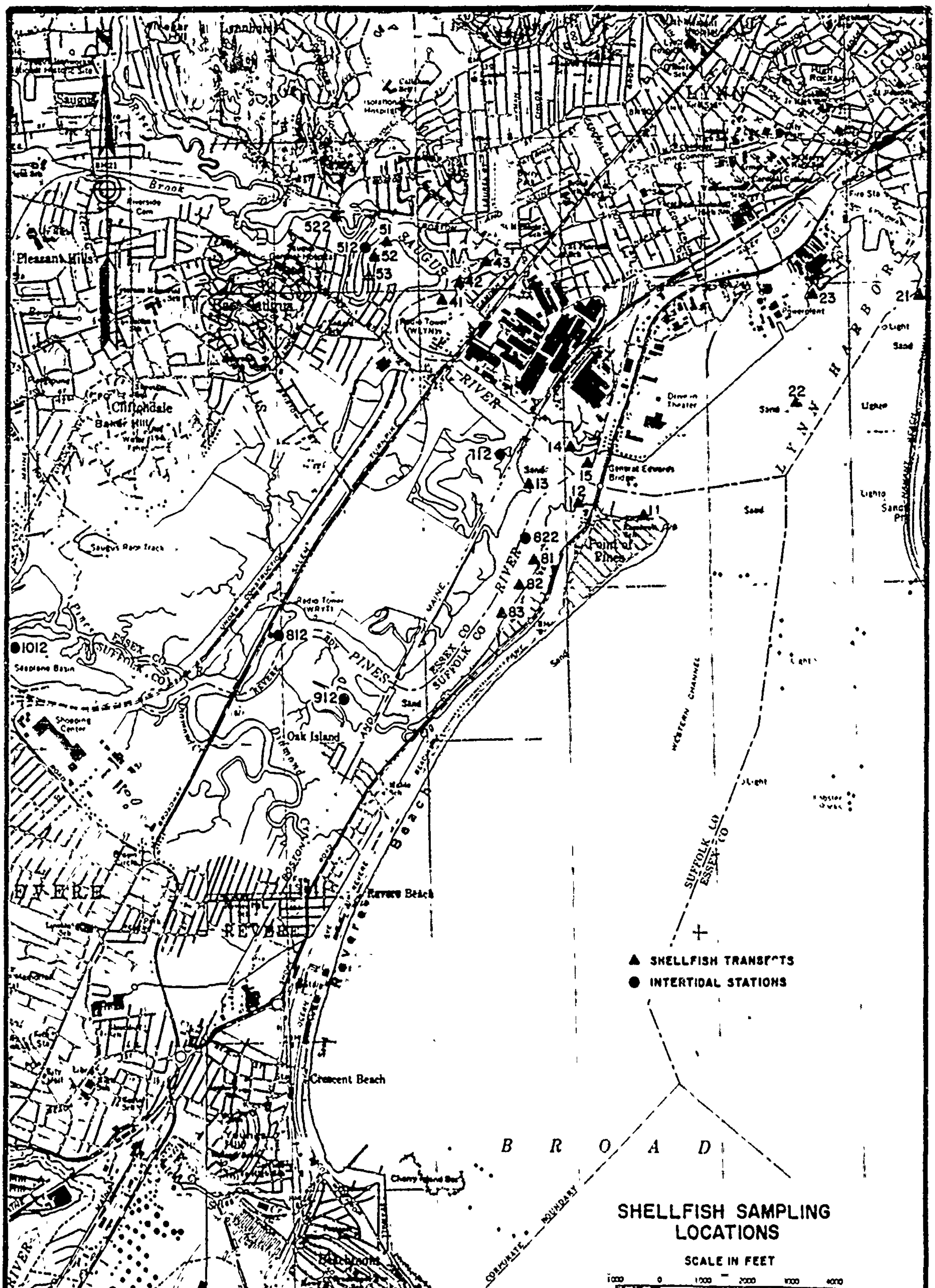
Table K32. SUMMARY OF PHYSICAL DATA COLLECTED AT INTERTIDAL STATIONS

		Tidal Level								
		Station 1 (High)			Station 2 (Mid)			Station 3 (Low)		
Area	Transect[c]	Grain Size	Redox (cm)	Presence of:[a]	Grain Size	Redox (cm)	Presence of:[a]	Grain Size	Redox (cm)	Presence of:[a]
1	11	Sand	2.0	--[b]	Sand	0.1	I	Sand	1.0	AL
1	12	Sandy silt	0.8	I	Sandy silt	0.1	H_2S, I	Shellhash/ Silty sand	0.1	H_2S
1	13	Clayey silt	0.4	I	Clayey silt	3.0	I	Fine sand	3.5	H_2S
1	14	Sand w/ Pebbles and Clay	3.5	H_2S	Sand	0.1	--	Sand	0.1	--
1	15	Silty sand /Peat	0.8	AL	Fine sand	--	EG	Clayey silt	0.1	I
2	21	Pebbley sand	0.0	--	Sand	0.1	H_2S	Silty sand	0.1	--
2	22	Sand	4.0	AT, I	Silty sand	1.0	I	Sand	2.5	--
2	23	Sand	0.7	I	Sand	0.1	H_2S, I	Silty sand	0.4	H_2S, I
4	41	Sandy silt	0.2	AL, I	Pebbley sand	0.2	I	Pebbley sand	1.0	--
5	(51)				Peaty silt	1.0	I			
5	(52)				Peaty silt	1.0	H_2S			
6	(61)				Clayey silt	10.0	AL, I			
7	(71)				Silty clay	3.0	AT, EG, H_2S, I			
8	(81)				Silty sand with peat	2.2	I			
8	(82)				Clayey silt	0.0	H_2S, I			
9	(91)				Silt	0.2	H_2S, EG AT, AL			
10	(101)				Sand	--	--			

[a] I = large invertebrate; AL = algae; AT = animal tubes; EG = eelgrass; H_2S = hydrogen sulfide odor.

[b] -- = not reported.

[c] Transects in parentheses are single stations.



▲ SHELLFISH TRANSECTS
● INTERTIDAL STATIONS
SHELLFISH SAMPLING
LOCATIONS
SCALE IN FEET
522
51
512
52
53
43
42
41
21
23
22
14
15
13
12
11
112
822
81
82
83
812
912
1012
Pleasant Hills
Cliftondale
Point of Pines
Oak Island
Revere Beach
Crescent Beach
Saugus River
Pines River
Lynn Harbor
Broad
Suffolk Co
Essex Co

FIGURE K22

Table K33. SUMMARY OF THE MEAN NUMBER OF SHELLFISH COLLECTED AT INTERTIDAL STATIONS

		Tidal Height					
		Station 1 (High)		Station 2 (Mid)		Station 3 (Low)	
Area	Transect [a]	$\bar{x}$ No./0.04m^2 (sd)	$\bar{x}$ No./m^2 (sd)	$\bar{x}$ No./0.04m^2 (sd)	$\bar{x}$ No./m^2 (sd)	$\bar{x}$ No./0.04m^2 (sd)	$\bar{x}$ No./m^2 (sd)
1	11	0	0	1.7 (1.5)	42.5 (37.5)	0.7 (0.6)	16.7 (15.0)
1	12	1.0 (1.0)	25.0 (25.0)	0	0	0	0
1	13	1.7 (0.6)	42.5 (37.5)	0	0	0	0
1	14	2.3 (1.2)	58.3 (30.0)	2.3 (3.2)	58.3 (80.0)	0	0
1	15	1.7 (2.9)	42.5 (72.5)	2.0 (2.0)	50.0 (50.0)	0	0
2	21	0	0	0	0	0	0
2	22	0.3 (0.6)	7.5 (14.4)	1.3 (2.3)	33.3 (57.7)	0	0
2	23	0	0	0	0	4.3 (6.7)	108.3 (167.5)
4	41	0.3 (0.6)	7.5 (14.4)	9.7 (8.4)	241.7 (210.0)	2.3 (1.2)	58.3 (30.0)
5	(51)			1.5 (1.0)	37.5 (25.0)		
5	(52)			0.3 (0.5)	7.5 (12.5)		
6	(61)			0	0		
7	(71)			2.0 (0)	50.0 (0)		
8	(81)			0.7 (0.6)	17.5 (15.0)		
8	(82)			141.0 (19.5)	3,525.0 (487.5)		
9	(91)			2.0 (0)	50.0 (0)		
10	(101)			2.3 (1.5)	58.3 (38.2)		

[a]Transects in parentheses are single stations.

Mytilus edulis and Geukensia demissa. The soft shell clam (Mya arenaria) and the Blue mussel (Mytilus edulis) were the most common shellfish collected in this survey.

Soft shell clams were found at high densities (up to $358/m^2$) in the upper Saugus River near the CSO (Area 4) and beyond (Area 5). Highest Mya densities were found at the mid tide-level. Soft shell clam densities in the Study Area are summarized, by location, in Table K34. The size distribution of Mya arenaria collected indicates the presence of several year classes in these areas (Table K35). Based on the minimum and maximum lengths of the individuals, the approximate ages ranged from one year (0-29.9mm) to over seven years (> 80.0mm) among the stations where Mya arenaria were collected (Brousseau, 1978). The areas that would be impacted by structures of the Regional Saugus River Floodgate Plan had low to moderate densities of soft shell clams, ranging from 0 to $108/m^2$. The average density at stations in these areas that yielded clams was $50/m^2$. Mussels were found in high concentrations along the shore of the Pines River (up to over $3000/m^2$)and along the Lynn Harbor shore (up to $100/m^2$). Abundances as high as $16,480/m^2$ have been reported near the mouth of the estuary (OESC, 1974).

Other species of clams were found in low densities. The razor clam, Ensis directus, was found incidentally in both the Pines and Saugus Rivers. Macoma balthica was found in the marshy areas (Areas 7 and 9) and Gemma gemma was found primarily in the Pines River marsh site (Area 9) and the Sea Plane Basin (Area 10).

Benthic Sampling Results by Area

The Confluence of the Pines and Saugus River (Area 1)

Subtidal sediment types at the mouth of the Saugus and Pines Rivers Estuary (Area 1) were characterized as silty sand and sandy silt. This homogeneity in sediment types is reflected in the benthic community. Species composition and mean abundance were similar among subtidal stations in this area.

The sediment grain size at the intertidal area near the mouth of the estuary (Area 1) is extremely heterogeneous. Sediment varied from sand to clayey-silt. These differences among stations were maintained at the different tidal heights. Significant differences ($p > 0.05$) in mean abundance and mean number of taxa were observed in all comparisons except the mean number of taxa at mid tide level. The mid and low tide stations generally exhibited higher mean abundances than the high tide stations (Table K31).

Table K34.

Soft shell clam densities in the Study Area (Mya/m^2).

Transect [a]	Station 1 High tide	Station 2 Mid tide	Station 3 Low tide
Area 1			
11	0	3	17
12	25	0	0
13	43	0	0
14	58	58	0
15	43	50	0
Area 2			
21	0	0	0
22	8	33	0
23	0	0	108
Area 4			
41	8	225	42
42	292	175	8
43	67	42	0
Area 5			
51	25	133	142
52	8	192	217
53	25	358	142
(512)		0	
(522)		0	
Area 6			
(612)		0	
Area 7			
(712)		8	
Area 8			
81	0	0	0
82	0	0	0
83	0	0	0
(812)		17	
(822)		8	
Area 9			
(912)		25	
Area 10			
(1012)		50	

[a]Transects in parentheses are single stations.

Table K35. MINIMUM, MAXIMUM, AND MEAN LENGTHS OF *MYA ARENARIA* COLLECTED AT INTERTIDAL STATIONS

Station	Mean (sd) (mm)	N	Minimum (mm)	Maximum (mm)
112	48.5 (31.9)	5	20.0	92.0
121	38.0 (20.2)	3	23.0	61.0
131	55.3 (31.5)	4	19.0	75.0
141	52.0 (26.3)	7	11.0	74.0
142	58.3 (29.8)	7	25.0	97.0
151	57.4 (5.6)	5	50.0	65.0
152	72.2 (18.3)	6	49.0	97.0
221	28.0 --	1		28.0
222	45.0 (11.2)	4	36.0	59.0
233	41.1 (13.6)	12	25.0	65.0
411	35.0 --	1		35.0
412	50.8 (12.5)	27[a]	25.0	70.0
413	46.6 (22.1)	5	17.0	75.0
712	30.0 --	1		30.0
812	59.5 (0.7)	2	59.0	60.0
912	55.3 (10.6)	3	44.0	65.0
1012	80.8 (11.4)	6	65.0	93.0

[a] Only 23 individuals used for the mean and sd calculation.

This area has moderate soft shell clam densities. Soft shell clams were found in 8 of the 15 stations in this area. Densities at these stations varied from $3/m^2$ to $58/m^2$ (see Table K34) for an average density of $37/m^2$. Averaging over all stations, _Mya_ densities in the area were $20/m^2$.

Lynn Harbor (Area 2)

The intertidal area along the eastern shore of Lynn Harbor (Area 2) is largely a sandy area dominated by oligochaetes and polychaetes such as _Caulleriella_ sp., _Nereis_ spp. and _Pygospio elegans_. The sediments become somewhat finer in the lower intertidal and there is a corresponding shift in the assemblage of benthic organisms to species associated with fine material (refer to Tables K30 and K32). Statistical differences in mean abundance and mean number of taxa were observed at each tidal height, the only exception being mean number of taxa at the mid tide level.

This area had low to moderate densities of soft shell clams. Soft shell clams were found in 3 of the 9 stations sampled and densities at these stations varied from $8/m^2$ to $108/m^2$ for an average density of $50/m^2$. Averaging over all stations, Mya densities in this area were $16/m^2$.

Large patches of mussel beds can be observed near the mouth of the estuary at low tide. Abundances as high as $16,480/m^2$ have been reported (OESC, 1974). High concentrations of mussels (as high as $100/m^2$) were found along the shores of Lynn Harbor.

The CSO Discharge on the Saugus River (Area 4)

Subtidal sediments in the vicinity of the Saugus River CSO discharge area (Area 4) were a sandy silt. This area was similar to other areas in terms of dominant organisms.

The sediments in the intertidal area ranged from a sandy silt in the low intertidal to a pebbly sand in the mid and high intertidal. Densities of individuals at this station were generally lower than at the muddy or marshy stations. The dominant organisms in this area were _Oligochaeta_ spp. and _Nereis_ spp.

This area had high soft shell clam densities. Soft shell clams were found in 8 of the 9 stations and densities at these stations varied from $8/m^2$ to $292/m^2$ for an average density of $107/m^2$. Averaging over all stations, _Mya_ densities in this area were $95/m^2$.

The Upper Saugus River (Area 5)

Subtidally, the upper Saugus River site (Area 5) had peaty-silty substrate. There was a high degree of variability in abundance of organisms among replicates at Area 5 (See Table K29).

Two intertidal stations were sampled in the upper Saugus River (Area 5). These stations (512 and 522) were located in very different exposure regimes. One station (512) was located on the easterly side of an

island in a protected area. This area was dominated by Streblospio benedicti and Oligochaetes. The other station (522) was located on the south side of the Saugus River just downstream of a bridge and had a more even distribution of organisms (See Table K30). The mean abundance was significantly higher ($P < 0.05$) at station 512 (the protected station) than at 522.

This area had the highest densities of soft shell clams. Soft shell clams were found in all nine of the stations in this area with densities varying from $8/m^2$ to $358/m^2$. Averaging over all stations, Mya densities were $138/m^2$.

Shute Brook (Area 6)

The Shute Brook area exhibited the least similarity with other stations in the subtidal survey. Only two of the dominant taxa common to the other subtidal stations were among the dominant taxa at this station (Table K27). Hypaniola florida, Cyathura polita and an Ampharetid polychaete were among the dominants at this station. The sediments in the Shute Brook samples (Area 6) were silty sand. Shute Brook had the highest bottom temperature, the highest dissolved oxygen concentration and the lowest bottom conductivity of all areas. Dissolved oxygen in this area was supersaturated (11.6 mg/l). Oxygen generation by benthic and planktonic algae is the most likely explanation for the high D.O. levels observed at this site. Comparable levels for D.O. were observed in the Saugus River in late winter and spring of 1984 and in April and May of 1986 and 1987 (MRI, 1987).

In the intertidal zone, fine grained sediments characterize the mid tide level, described as clayey-silt, suggestive of an area of low flow, or a depositional environment. Mean abundance and mean number of taxa at this station were slightly lower than at the other study areas. Oligochaetes were the dominant taxa at this station and are generally indicative of stressed or freshwater conditions. No soft shell clams were found in Area 6.

The Pines River (Area 8)

Differences in the benthic infauna at the subtidal Pines River stations reflect differences in sediment characteristics at the two subtidal stations. One station (802) was located approximately 900 meters from the confluence of the Saugus and Pines River in clayey-silt; the other (801) was another 900 meters upstream in silty sand. The muddy subtidal station had significantly higher abundances, and was dominated by opportunistic species, such as Capitella spp., Streblospio benedicti, Polydora ligni and oligochaetes, characteristic of muddy bottoms. The sandier subtidal station had lower abundances and more even distribution of organisms, with species such as Paraonis fulgens and Caulleriella sp. being among the dominants.

In the Pines River, the two intertidal stations within Area 8 (812 and 822) were very different from each other. Station 812 was on a sand bar in the Upper Pines River, while Station 822 was on a mud flat in the Pines River near its confluence with the Saugus River. Mean abundance and mean number of taxa were higher at Station 822 than at station 812, but statistical comparisons did not detect significant differences between the stations.

The Pines River had relatively low densities of soft shell clams. *Mya* densities of 17 *Mya*/m^2 were found at the sand bar station (812) and 8 *Mya*/m^2 at the muddy station (822). No soft shell clams were found in the three transects (81, 82, 83) along the lower reach of the Pines River. This area does not appear to be good soft shell clam habitat. The upper and mid tidal heights were characterized by a fine to medium sand, with poor water retention. Tidal water drains quickly with the outgoing tide, leaving the area too dry for soft shell clams. At the low tide mark, the sediments were generally too gravelly for *Mya*. Averaging over all stations, *Mya* densities in the area were a little more than $2/m^2$. The muddy intertidal area was essentially a mussel bed, with relatively low *Mya* densities. This area had the highest shellfish densities reported (3525 individuals/m^2) in the Study Area. Individuals ranged in size from 5.0 to 60.0mm, with the greatest number of individuals falling between 6.0 and 30.0mm.

Marsh Sites (Areas 7 and 9)

The marsh stations in the Saugus (Area 7) and Pines (Area 9) Rivers had the highest density of individuals of all subtidal stations. Both stations were dominated by the polychaete *Streblospio benedicti* which represented 68.2 and 62.2 percent of the fauna, respectively.

The mid tide intertidal stations in Areas 7 and 9 were in marshy locations with very fine sediments. Algae, eelgrass, animal tubes and hydrogen sulfide odors were present at both stations. Marshy areas are indicative of low circulation, and can receive high inputs of organic materials. The presence of hydrogen sulfide odors and fine substrates suggests that these two areas were organically enriched. Further evidence of organic enrichment was exhibited by high mean abundance, and by the composition of the dominant taxa. Mean abundance and mean numbers of taxa were higher at these two stations than at other mid tide stations among all areas sampled. Station 912 had the highest mean abundance and mean number of taxa among all of the mid tide level stations (See Table K31). The dominant taxon at Station 712 and 912 were *Streblospio benedicti* which represented 63.0 and 83.3 percent of the fauna, respectively.

Mya arenaria and *Macoma balthica* were found in both marsh areas. Mya densities of $25/m^2$ and $8/m^2$ were found at the Pines River and Saugus River marsh sites, respectively.

The Sea Plane Basin (Area 10)

The subtidal fauna at Sea Plane basin (Area 10) was more similar in species composition to the more sandy stations (e.g. Station 801).

The mid tide intertidal station in Area 10 (Sea Plane Basin) was sandy. Mean abundance was the lowest of the mid tide stations. Species composition was different from that at the more muddy stations. The dominant taxa at this station were *Nereis* spp., oligochaetes, *Gemma gemma* and *Streblospio benedicti*.

Moderate *Mya* densities (50/m^2) were found in this area.

J. Sandy Beaches

The only sandy beach in the Study Area is that which forms a crescent shaped barrier spit which is bordered by Broad Sound to the east and the Pines and Saugus Rivers to the west (see Figure K1). It extends from the east end of Roughans Point through the Point of Pines area for approximately three miles. The segment from roughly Eliot Circle on the south to Carey Circle on the north is known as Revere Beach. From Carey Circle north to the mouth of the Saugus River is known as Point of Pines. Coastal erosion and fluctuating sea levels have contributed to the formation of the beach which is composed of Saugus River sand and offshore sand of late glacial age (HMM, 1986). Protection provided from severe storms by Lynn Beach has enabled the beach to grow northward to the mouth of the Saugus River at Point of Pines.

Prior to urbanization, it would be reasonable to assume that Revere Beach and Point of Pines had resembled a typical northeastern coastal barrier beach. A well-developed barrier beach ecosystem frequently supports a primary dune system dominated by American beach grass (*Ammophila breviligulata*). The more stable inland dunes are usually inhabited by a heath-like community of low shrubs, and if the conditions are right, a woodland vegetation community can develop behind the dunes typically containing members of the rose family (Godfrey, 1976). In many cases, salt marshes are able to develop behind barrier beaches because of the protection these beaches provide from ocean waves. This is true for both Revere Beach and the adjacent beach at Point of Pines which protect an extensive estuarine salt marsh.

Revere Beach has been altered by over one hundred years of urban development. As a result, only a narrow beach with no dunes or beach vegetation remains.

The Revere Beach Reservation is owned and maintained by the Metropolitan District Commission (MDC) and is the oldest public beach in the country (USACE, 1983a; HMM, 1986). Access to the beach is provided by an adjacent mass transit railway stop and Revere Beach Boulevard which extends the length of Revere Beach. Revere Beach was once a popular public recreation facility for the Boston metropolitan area, and included an amusement park, bars, arcades, and restaurants (USACE, 1983a). This area is now being restored under a Master Plan started in the late 1970s (MDC, 1979). The Master Plan proposes new residential and commercial development and a linear park system. The Master Plan would incorporate traffic improvements, as well as restoration of historic structures to accommodate food concessions, sanitary facilities, bathhouses, amusements, police and maintenance requirements.

Revere Beach is so narrow that waves hit the Revere Beach seawall at high tide in some areas. Beach profile surveys conducted over the last 140 years have demonstrated that beach sand generally erodes from the central portion of the beach in the vicinity of the bathhouse pavilions (USACE, 1985a). This is due to the advanced development of the backshore and the erection of protective seawall structures. These structures have eliminated the source of localized littoral materials to the shore which formerly provided some equilibrium under natural shore processes (USACE, 1985a). Buildup of material occurs primarily to the north off of Point of Pines and to a lesser extent to the south in the small embankment formed by Roughans Point.

To offset the loss of beach material, the MDC placed approximately 172,000 cubic yards of sandfill on Revere Beach in 1954. Subsequent beach erosion control studies conducted by the Corps of Engineers have recommended the placement of an additional 760,000 cubic yards of sand.

Revere Beach is composed of fine to medium textured sand with a small percentage of silt and gravel (USACE, 1985a). The sand is a mainly gray color,
although individual minerals vary from white quartz and buff colored feldspar to reddish brown and black particles. At lower elevations, organic matter accumulates in the sand particles producing an even darker gray cast to the beach. Pockets of gravel and cobble remain on the beach from high energy storms and hurricanes which stir up pieces of gravel offshore and deposit them on the beach. This represents the remainder of the glacial till that supplied much of the sediment in the area (Bohlen, 1978).

The beach at Point of Pines extends northward from Revere Beach to the mouth of the Saugus River. Point of Pines is a sand spit composed of deposited river sands (USACE, 1984a). Most of the Point of Pines area is occupied by a densely developed single family neighborhood which is protected by a seawall along the river side of Rice Avenue. The beach area facing Broad Sound supports some developed foredunes and beach vegetation. The dunes are inhabited by American beach grass (Ammophila breviligulata), dusty miller (Artemisia stelleriana) and beach rose (Rosa rugosa). These species provide habitat for migratory birds, especially in the late summer and early fall (U.S. Fish and Wildlife Service, 1982). Minimal beach vegetation exists on the river (northern) side of Point of Pines.

Fauna inhabitation of the Revere and Point of Pines beaches is limited due to the heavy backshore development and recreational use of the beaches. Nevertheless, birds such as gulls, terns, shorebirds and waterfowl may be seen there, as well as rodents, such as rats and mice. The strand line, composed of seaweed (Fucus sp. and other algae) and jetsam, can provide a moist environment for beach-hoppers or the amphipods Orchestia, Talitrus and Talorchestia (Berrill, 1981). Species found on the dunes at Point of Pines might include the dune wolf spider (Lycosa pikei), seaside grasshopper (Trimerotropis maritima), and antlions (family Myrmeleontidae) (Costello, 1980) as well as migratory passerine birds, especially in the late summer and early fall (USFWS, 1982).

K. Artificial Shorelines

Based on maps dated 1900 and a USGS map dated 1946 it can be determined that many of the flood control structures now bordering Lynn Harbor and the Saugus and Pines Rivers Estuary were constructed sometime in the first half of the twentieth century.

Approximately 8300 feet of dikes and walls exist along the Lynn Harbor shoreline from the location of the General Edwards Bridge north to the Harborside Landing Condominium project. The dikes and walls designed to protect development behind the structures are composed of wood bulkheads, stone riprap and metal sheet piling. The wood bulkhead located at the north

end of the General Edwards Bridge is in ill-repair and would require eventual replacement. Prior to the construction of the flood control structures along Lynn Harbor, the unfilled area behind the structures contained portions of the Saugus River marsh. This area is now filled and contains flood control structures built to protect the development behind these structures. Other artificial structures in the Study Area include the supports of the General Edwards Bridge, pilings of the fishing piers, revetments and bulkheads at the mouth of the Saugus River and various other flood control structures throughout the periphery of the estuary.

Flora and fauna observed inhabiting the walls and dikes along Lynn Harbor are similar to species typical of open rock surfaces. That is, these species are either attached (e.g. barnacles, mussels and many types of algae) or, if mobile, capable of holding tightly to the surface, such as limpets and periwinkles (Barnes, 1977). The zonal distribution of intertidal organisms on rocky shores is a universal occurrence. Zone level and width are dependent on the degree of exposure to wave action (Newell, 1979). The same factors which contribute to the zonation of intertidal organisms on rocky shores would also be expected to influence the intertidal organisms along the Lynn Harbor shorefront. Species observed in the Study Area are typical of rocky shore species.

The zone of barnacles (_Balanus_ spp.) marks the upper limit of the intertidal zone (Berrill and Berrill, 1981). Other competitors cannot tolerate the duration and degree of exposure in the upper intertidal zone. Along the Lynn Harbor shoreline, barnacles extend from the bottom of the flood control structures to a height of about six feet. Located from the bottom of the flood control structures to a height of about three feet are the brown rockweeds (_Fucus_ spp.) and the periwinkle _Littorina littorea_. Located at the bottom of the structures are the blue mussel (_Mytilus edulis_) and the knotted wrack (_Ascophyllum nodosum_). Brown rockweeds and blue mussels are the barnacles' primary competitors. They can determine barnacle density in the lower range of the barnacle zone (Berrill and Berrill, 1981). The earlier-mentioned structures at the mouth of the Saugus River, including the supports of the General Edwards Bridge, are also capable of supporting these types of species.

In general, the type of the flood control structure along Lynn Harbor did not seem to affect the species composition of the organisms attached to the structure. The only exception is the metal sheet piling which was found to contain only barnacle and brown rockweed species.

Salinity can, however, determine the species populating flood control structures in the Study Area. Species inhabiting flood control structures in the marsh near the mouth of the Saugus River are similar to species observed along the Lynn Harbor shoreline. As salinity decreases upstream in the Pines and Saugus Rivers, so does the abundance of estuarine organisms inhabiting the flood control structures in the marsh. Estuarine organisms decline in abundance as one moves upstream until these species are no longer observed populating these structures. Few, if any, freshwater species are noted as replacements. Freshwater flora and fauna expected to utilize the flood

control structures as habitat would include species of filamentous green and bluegreen algae, gastropods (snails), and members of Ephemoptera (mayflies).

L. Plankton

General

Recent studies by MRI (1985) concerning the ichthyoplankton (planktonic fish eggs and larvae) of the Saugus and Pines Rivers are summarized in the Fish section of this Appendix. Additional studies concerning the zooplankton and phytoplankton of Lynn Harbor and Nahant Bay were conducted between 1970 and 1974 (Raytheon, 1974) and are summarized below. No new field studies were conducted for this report.

Because the Saugus and Pines Rivers Estuary is well mixed and strongly influenced by tidal flushing, planktonic communities in much of the Saugus and Pines Rivers are likely dominated by species imported from Lynn Harbor or suspended from disturbed benthic sediments (thycoplankton). In order for a truly indigenous planktonic population to persist in an estuary, its growth rate must be at least equal to losses due to tidal flushing and mortality caused by predation or other factors (Smayda, 1983; Miller, 1983). Given the flushing rate of the estuary (the mean volume of the estuary flushed per tidal cycle is estimated to be ca. 80%), a very rapid generation time (ca. 2.5 hours) would be required to maintain an indigenous planktonic population. Because this rate is more rapid than the likely growth rate of estuarine zooplankton (Durbin and Durbin, 1981) or phytoplankton (TRIGOM, 1974), an indigenous planktonic population cannot persist in the tidally influenced portion of the estuary. The planktonic community present in much of the estuary thus depends on continued recruitment from Lynn Harbor, the upper (freshwater) reaches of the Saugus and Pines Rivers and from epibenthic communities. Given the magnitude of tidal exchange, extensive areas of mudflat and emergent marsh habitat and limited freshwater inputs, most plankton present in the Saugus and Pines Rivers probably originate from Lynn Harbor or epibenthic communities.

Phytoplankton Community Composition and Abundance in Lynn Harbor

Raytheon (1974) noted representatives of 59 genera from Lynn Harbor and Nahant Bay. Diatoms, a common class of yellow green algae, were dominant in all samples and typically accounted for > 90% of the total number of phytoplankton enumerated. Phytoplankton communities of coastal and estuarine New England waters are generally reported to be dominated by diatoms (TRIGOM, 1974; Toner, 1984a). Predominant diatom genera noted in the Raytheon study (Chaetoceros, Skeletonema, Leptocylindrus, Rhizosolenia and Thalassiosira) are all typical components of the Gulf of Maine flora.

Although the red tide dinoflagellate, Gonyaulax tamarensis is known to occur in Massachusetts coastal waters (Mulligan, 1973) it was not noted from Lynn Harbor or Nahant Bay in the Raytheon (1974) study.

Average phytoplankton densities in Lynn Harbor in 1973-1974 ranged between 9 cells/ml in January to 1989 cells/ml in September. Average

chlorophyll concentrations ranged from 2.7 mg/m^3 in February to 10.7 mg/m^3 in September. Spring phytoplankton peaks occurred in either April or June. Fall peaks occurred in September or October. The occurrence of supersaturated dissolved oxygen levels in the Saugus River in the winter and spring of 1984 (MRI, 1985) and spring of 1987 (MRI, 1987) provides indirect evidence of high phytoplankton densities during those times. Spring and late summer-early fall abundance maxima are typical in the Gulf of Maine (TRIGOM, 1974).

Very small plankton (nanoplankton), which can account for a substantial percentage of total productivity in coastal marine waters, were not adequately sampled in the Raytheon study. Recent studies by MWRA (1987) indicate that nanoplankton account (on average) for over 70% of total July - September phytoplankton production and chlorophyll standing crop in nearshore Massachusetts Bay waters.

Phytoplankton Productivity

Given the predominance of emergent macrophytes in the Saugus and Pines Rivers Estuary, phytoplankton, benthic algae and benthic macrophytes in the Saugus and Pines Rivers probably account for only a small percentage of total estuarine production. In situ production of phytoplankton in estuarine rivers and mudflats is generally greater than that of benthic algae, but less than that of benthic macrophytes (Welsh et al., 1982). In the Saugus and Pines Rivers Estuary benthic macrophytes appear to be largely absent from the river or mudflats, so riverine production may be dominated by phytoplankton.

Productivity of phytoplankton in estuaries is limited by light availability, and becomes strongly reduced as suspended particulate matter concentrations increase from 10 to 100 mg/l (Cloern, 1987). Because lowest suspended sediment levels in the estuary are likely to be ca. 10 to 30 mg/l, it is probable that phytoplankton production in the Saugus and Pines Rivers Estuary is limited to some extent by light availability.

Zooplankton Community Composition and Abundance in Lynn Harbor

Raytheon (1974) studied the zooplankton (including mero- and ichthyoplankton) of Lynn Harbor and Nahant Bay from August 1970 to February 1974. A total of ca. 190 planktonic invertebrate species were recorded. Species richness generally was lowest during winter months, peaked during the spring, and declined through the fall. Approximately 60% of invertebrate taxa noted were arthropods. Frequently occurring taxa included the copepods *Acartia*, *Calanus*, *Centropages*, *Temora*, *Tortanus*, the isopod *Idotea baltica*, the mysid *Neomysis americana* and the arrowworm *Sagitta elegans*. Macrozooplankton communities of New England coastal waters are typically dominated by copepods (TRIGOM, 1974; Durbin and Durbin, 1981; Toner, 1984b).

Larvae of American lobster (*Homarus americanus*) were noted in most months, but occurred most frequently during August-November. Larvae of the soft shell clam (*Mya arenaria*) were noted during April-August.

Zooplankton abundance varied seasonally, with peaks generally occurring in spring and fall. Average densities in Lynn Harbor ranged from ca. 40 organisms/m^3 during the mid winter (December-February) to ca. 210 organisms/m^3 in the spring (March-May). These values should be viewed only in relative terms, because the 500 um mesh plankton net used in the Raytheon study is too coarse for quantitative sampling of estuarine zooplankton. Zooplankton peaks in estuaries are typically synchronized with peak periods of phytoplankton production (Toner, 1981).

M. Fish

Historical Conditions

The Saugus and Pines Rivers area has supported subsistence level fisheries since the area was first inhabited by native Americans. Preferred species included Atlantic salmon (Salmo salar), sea run trout (Salmo sp.) and striped bass (Morone saxatilis) (Lynn School Committee, 1931, cited by Chesmore et al., 1972).

With the arrival of English colonists in the 17th century, the fishery resources were exploited for both subsistence and commercial purposes. Anadromous fish, including striped bass and alewives (Alosa pseudoharengus) were the principal commercially exploited species (Lewis and Newhall, 1865, cited by Chesmore et al., 1972). Herring (clupeids) and cod (Gadus morhua) were also of importance to these early colonists.

The establishment of the dory and line trawl fisheries in the mid-nineteenth century led to the targeting of haddock (Melanogrammus aeglefinus, cod, mackerel (Scomber scombrus) and tautog (Tautoga onitis) (Chesmore et al., 1972). By the latter half of the 1800's, the area's (Lynn-Nahant-Swampscott district) fisheries were producing large quantities of fish and fish products. Heavy fishing pressure, and presumably habitat degradation, led to the extirpation of salmon, shad (Alosa sapidissima) and bass from the estuary by the turn of the 20th century (Chesmore et al., 1972).

Recreational fisheries became important in Lynn Harbor by the 1950's (Chesmore et al., 1972). Targeted species included mackerel, cod, haddock, pollock (Pollachius virens) and winter flounder (Pseudoplueronectes americanus). By this time, striped bass and presumably shad were reestablished in the harbor and also sought by recreational fishermen.

Shurtleff (1938) (cited by Chesmore et al., 1972) provides one of the earliest comprehensive listings of finfish species occurring in the Lynn area Species reported include bluefish (Pomatomus saltatrix), bream (Archosargus rhomboidalis), catfish (Anarhichas spp.), cod, conger eel (Conger oceanicus), dogfish (Squalus acanthias), eel (Anguilla rostrata), English hake (Merluccius billinearis), winter flounder, frostfish (Microgadus tomcod), goosefish (Lophius spp.), ground shark (Carcharias taurus), haddock, hake (Urophycis spp.), herring, mackerel, mackerel shark (Lamna nasus), minnow (Fundulus spp.), perch (Tautogolabrus adspersus), pollock, porgy (Stenotomus chrysops), sand eel (Ammodytes spp.), sculpin (Cottidae), skate (Raja spp.), skipjack (Euthynnus pelamis), smelt (Osmerus mordax), sunfish (Mola mola) and tautog.

In the 1960's the Massachusetts Division of Fisheries and Wildlife (MDFW) initiated a stocking program for the anadromous sea run brown trout (Salmo trutta) in the Saugus River. This effort was designed to establish a self-reproducing stock in the river. The fish were released near the Saugus Iron Works in quantities ranging from 500 in 1964 and 1965 to 100 fish each year in 1967 and 1968 (HMM Associates, 1986). The program was curtailed in 1968 due to the poor water quality conditions of the river. Brown trout stocking was reinitiated in 1982 by Trout Unlimited and the Malden Anglers (in association with the MDFW). Some 400 to 850 smolts were released near the Iron Works each year, through 1985 (HMM Associates, 1986). The MDFW released 300 smolts into the upper Saugus River in 1986 and 300-400 in 1988. Smolts were released in the spring (April-May) near where the river crosses Central Street and Route 93 (Peter Jackson, MDFW, 1988 - Personal Communication).

Existing Conditions

Introduction

Recent studies of the fisheries resources of the Saugus and Pines Rivers Estuary and/or Lynn Harbor include those by the Massachusetts Division of Marine Fisheries (Chesmore et al., 1972) during 1968-1969, studies by Raytheon (1974) from 1970-1974, studies by Marine Research Inc. (MRI, 1985) during 1984, and field studies conducted for this report. The Division of Marine Fisheries study reviewed the status of the area's fisheries and the condition of the estuarine habitat. The Raytheon study provides data concerning the ichthyoplankton and finfish in Lynn Harbor and near the mouth of the Saugus River. The MRI program sampled ichthyoplankton and finfish in the Saugus River as part of the preoperational studies for a power generating unit at the Refuse Energy Systems Company (RESCO) plant in Saugus.

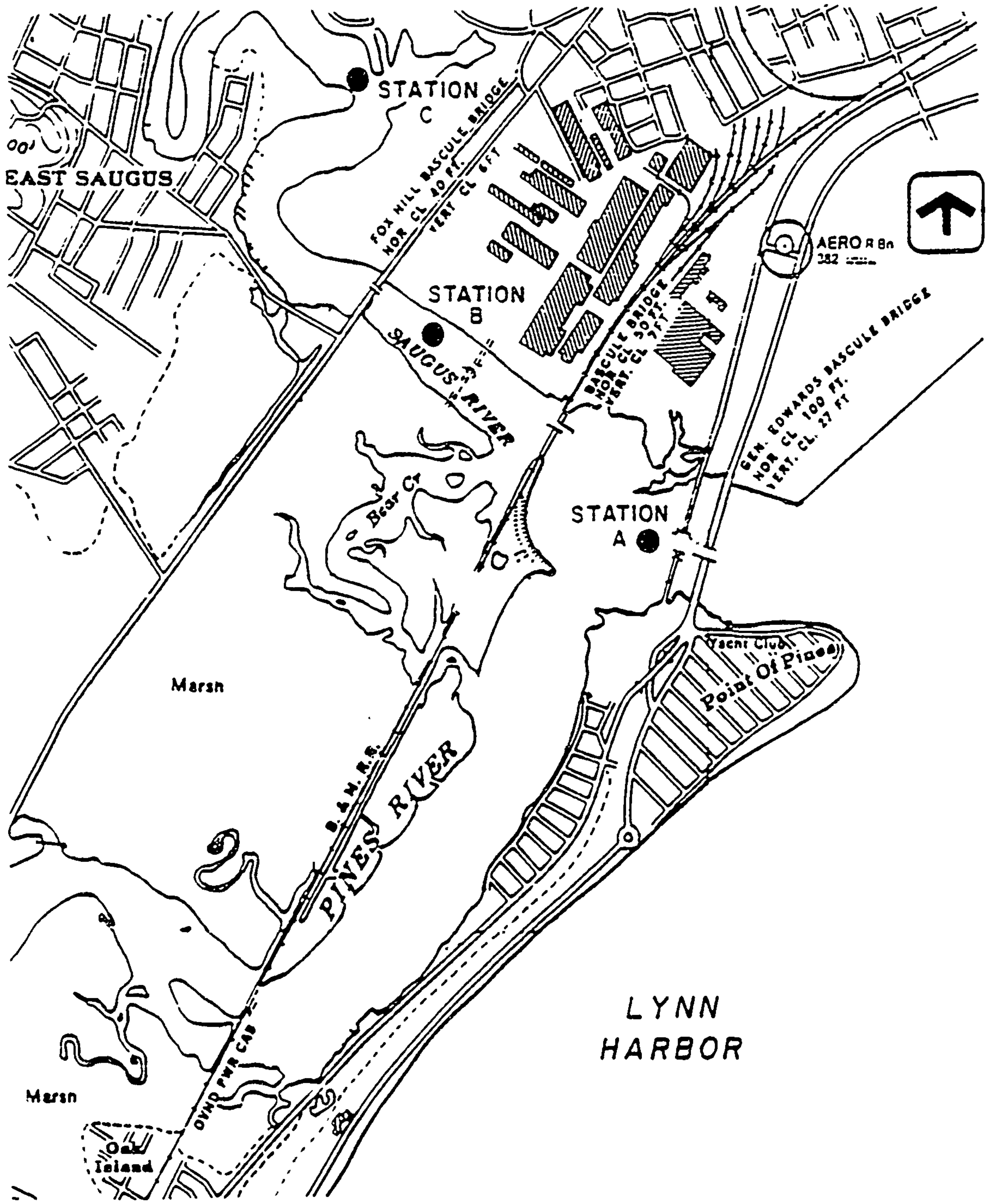
Ichthyoplankton

Existing Resources

Marine Research, Inc. sampled the estuary ichthyoplankton at three stations from February through December of 1984 (MRI, 1985). Sampling station locations are shown in Figure K23, and are essentially all located in the Saugus River portion of the estuary.

The seasonal occurrence of ichthyoplankton in the Saugus River as reported by MRI (1985) is presented in Table K36. A total of 34 species were identified. Eggs and larvae of several commercially important species such as menhaden, cod, butterfish (Peprilus triacanthus) and flounders were found at all sampling stations. The species richness for both eggs and larvae was greatest during June (Figures K24B and K25B).

Egg density was highest during June (Figure K24A). Predominant species in terms of egg density during this time were tautog, cunner, mackerel and the flounders. Fairly high egg densities extended form May into mid-summer. Studies by Raytheon (1974) indicate that peak egg density in Lynn Harbor also occurs in June. Larval density peaked in April as a result of



SOURCE NOS # 13270

Figure K23. Marine Research, Inc., Ichthyoplankton Sampling Stations, February - December 1984

Table K36. Distribution of Saugus River Ichthyoplankton by Sampling During February to December 1984[1]

		Month/Station																																
	SPECIES	Feb			Mar			Apr			May			Jun			Jul			Aug			Sep			Oct			Nov			Dec		
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
American eel	*Anguilla rostrata*									l			l																					
Atlantic menhaden	*Brevoortia tyrannus*													e	e/l	e	e/l																	
Atlantic herring	*Clupea harengus harengus*				l	l		l	l	l																l			l	l	l	l	l	l
Anchovy	*Anchoa* spp.																							l										
Rainbow smelt	*Osmerus mordax*							l	l	l	l	l	l																					
Goosefish	*Lophius americanus*																				l			l	l									
Fourbeard rockling	*Enchelyopus cimbrius*							e	e	e	e	e	e	e/l	e/l	e/l	e	l		e/l	e	l	e/l	e	e									
Atlantic cod	*Gadus morhua*	l	e/l		e	e	e	e	e		e/l	e	e	e												e			e	e	e	e	e	e
Haddock	*Melanogrammus aeglefinus*												e																					
Silver hake	*Merluccius bilinearis*													e/l	e										l									
Pollock	*Pollachius virens*								e																								l	
Hake	*Urophycis* spp.													e	e		e/l			e/l	e	e	e											
Silverside	*Menidia* spp.													l	l	l		l	l			l												
Threespine stickleback	*Gasterosteus aculeatus*															l																		
Northern pipefish	*Syngnathus fuscus*							l						l	l	l	l	l	l	l	l	l		l	l	l	l	l	l					
Wrasses	Labridae										e	e	e	e	e	e	e	e	e	e	e	e	e	e	e									
Tautog	*Tautoga onitis*														l					l	l				l									
Cunner	*Tautogolabrus adspersus*													l	l	l	l			l	l	l												
Radiated shanny	*Ulvaria subbifurcata*							l	l	l	l	l	l	l			l																	
Rock gunnel	*Pholis gunnellus*				l	l	l	l	l	l																								
Sand lance	*Ammodytes* sp.				l	l	l	l	l	l	l	l		l																				
Atlantic mackerel	*Scomber scombrus*										e			e/l	e/l	[illegible]	l																	
Butterfish	*Peprilus triacanthus*																						e	e	e				l					
Grubby	*Myoxocephalus aenaeus*				l	l	l	l	l	l	l	l																						
Longhorn sculpin	*M. octodecemspinosus*				l	l																												
Shorthorn sculpin	*M. scorpius*				l		l																											
Seasnail	*Liparis atlanticus*							l	l	l	l																							
Gulf snailfish	*L. coheni*				l	l																												
Windowpane	*Scophthalmus aquosus*							e		e				l	l	l		l		l	l	l	l	l	l									
Witch flounder	*Glyptocephalus cynoglossus*										e	e		e/l	e	l	e			e			e											
American plaice	*Hippoglossoides platessoides*				e	e	e/l	e/l	e/l	e/l	e/l	e/l	e/l	e/l			l	e		l														
Yellowtail flounder	*Limanda ferruginea*							e	e	e	e/l	e/l	e	e/l		l	e																	
Smooth flounder	*Liopsetta putnami*									l																								
Winter flounder	*Pseudopleuronectes americanus*				e	e	e	e/l	e/l	e/l	l	l	l		l																			

l - larvae e - eggs

[1] Based on data presented in Marine Research, Inc., 1985

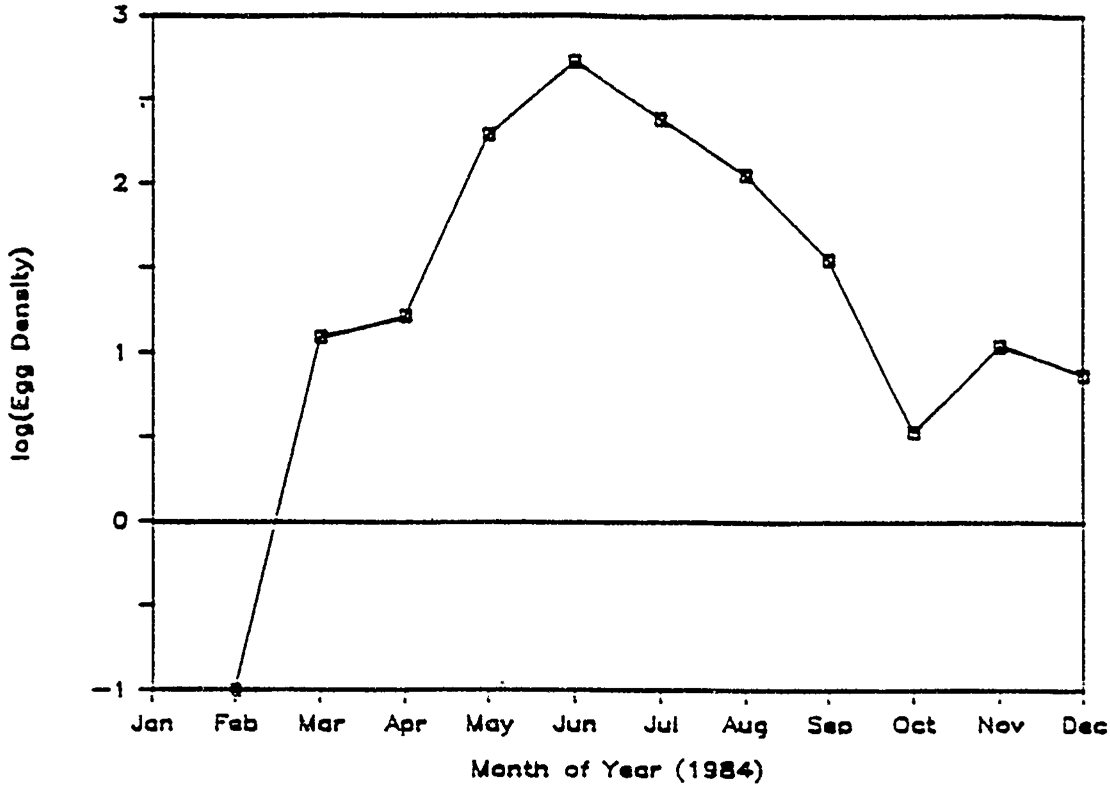


Figure K24A. Mean Monthly Density of Fish Eggs per $100m^3$ of Water
(source: MRI, 1985)

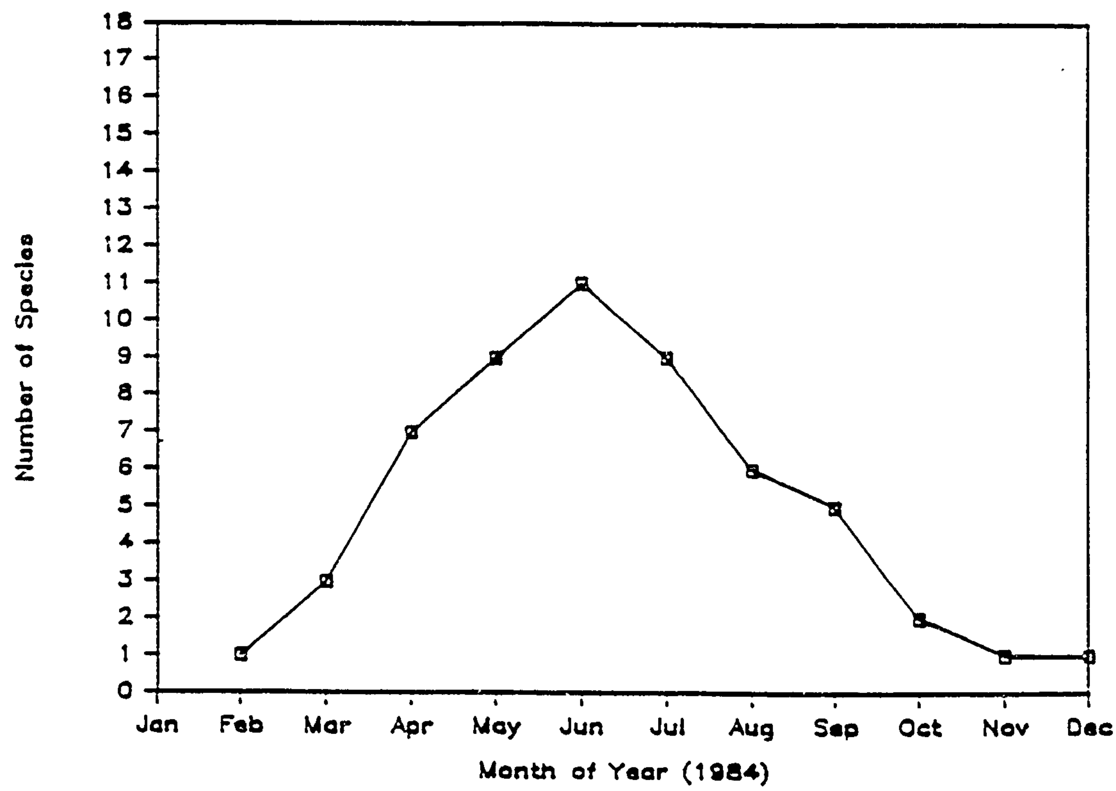


Figure K24B. Number of Species Identified as Eggs by Month
(source: MRI, 1985)

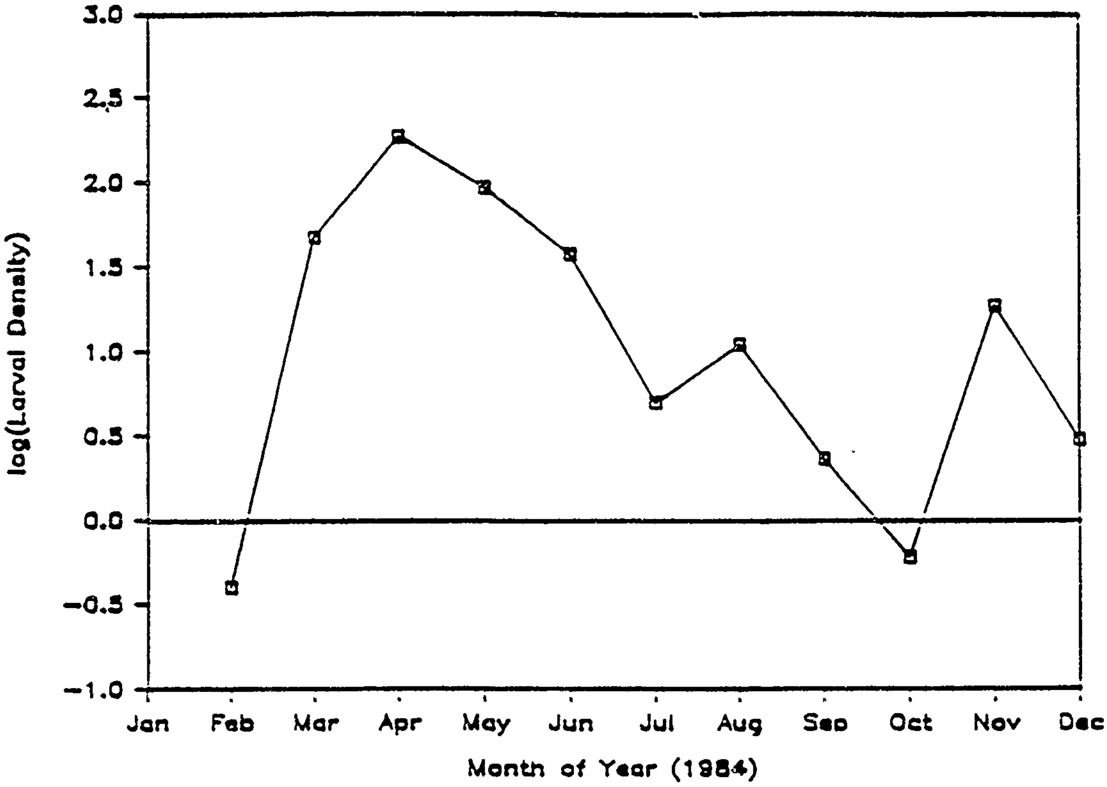


Figure K25A. Mean Monthly Density of Fish Larvae per 100m^3 of Water (source: MRI, 1985)

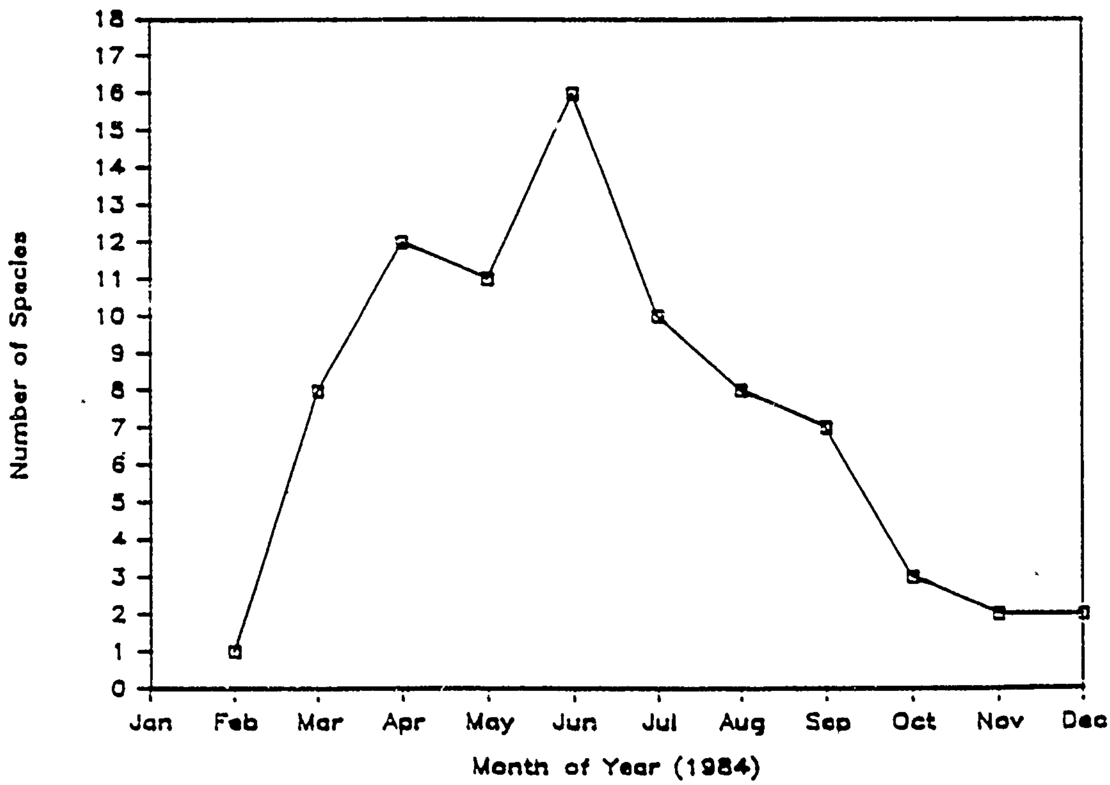


Figure K25B. Number of Species Identified as Larvae by Month (source: MRI, 1985)

winter spawning by species such as Atlantic herring, rainbow smelt, radiated shanny (*Uluaria subbifurcata*), rock gunnel (*Pholis gunnellus*), sand lance (*Ammodytes*) and sculpins (*Myoxocephalus* spp.). Fairly high larval densities extended from March into June. A much lower secondary peak occurred in late fall due to Atlantic herring (Figure K25A). Mean monthly densities of individual taxa for both eggs and larvae are presented in Table K37.

Species Synopsis (Ichthyoplankton)

Eggs of rainbow smelt, an anadromous species, were likely to have been spawned in the upper reaches of the Saugus River above the influence of tides. Eggs are adhesive and demersal and likely to be rare in ichthyoplankton samples. Although smelt larvae were collected at all stations, most were found at Station C, further confirming upstream spawning. The mean total length of smelt larvae collected in April was 5.9mm (n=55) while in May samples mean length was 7.0mm (n=37). This suggests that the same stock of smelt were sampled over the two months and utilized the estuary as a feeding area prior to their departure to the open coastal waters in June.

Atlantic menhaden eggs present in the Saugus River during June and July were spawned offshore and transported into the estuary by tidal currents. Larvae probably utilize the estuary as a nursery area, and return to the sea as juveniles in September or October (Clayton et al., 1978).

Herring eggs are demersal and adhesive and likely to have been spawned in nearshore waters. Larvae are transported into the estuary by tidal currents. The prolonged presence of larvae in the estuary reflects the variable spawning behavior of this species. Leim and Scott (1966) indicate that spawning in Canadian waters to the north of Massachusetts occurs mainly in May and August, but that spawning may occur from April through November.

Eggs and larvae of the fourbeard rockling occur within the estuary. Little is known concerning the breeding habits of this species in North American waters. Leim and Scott (1966) indicate that normal development for this species occurs between water temperatures of 55-66° F (13-19° C) and at salinities of 18.6-45 ppt. These are ambient conditions in the Saugus River during the spring and summer months and, therefore, development could occur in the river. The data suggest a protracted (6 month) spawning period for this species.

Atlantic cod eggs appeared in nearly every monthly sample with the exception of July, August and September. The buoyant eggs are likely to have been spawned in Massachusetts Bay and transported by currents into the Saugus River. This species is known to spawn in March and again from late September through December (Leim and Scott, 1966). The small number of larvae collected suggest that the estuary may not be a preferred nursery area for this species.

The occurrence of silver hake and hake (*Urophycis* spp.) eggs and larvae suggest that these species utilize the estuary as a nursery area. Eggs of these species are buoyant and were likely to have been spawned

Table K37. Mean monthly densities, per 100 m^3 of water, for eggs and larvae collected at three stations in the Saugus River, 1984.

Species		Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
EGGS												
Atlantic menhaden	Brevoortia tyrannus	0	0	0	0	1.9	0.1	0	0	0	0	0
Codfish-Witch flounder	Gadidae-Glyptocephalus	*	0	0.3	2.3	0.1	0.4	0	0	3.1	0	0
Rockling-Hake-Butterfish	Enchelyopus-Urophycis-Peprilus	*	*	*	2.4	5.5	5.2	7.7	0.4	0	0	0
Fourbeard rockling	Enchelyopus cimbrius	0	0	0.5**	0.6	2.3	0.2	0.4	0.3	0	0	0
Atlantic cod	Gadus morhua	0.1	5.0	1.5	2.1	0.1	0	0	0	0.1	11.1	7.4
Haddock	Melanogrammus aeglefinus	0	0	0	0.1	0	0	0	0	0	0	0
Silver hake-Scup-Weakfish	Merluccius-Stenotomus-Cynoscion	0	0	0	0	0.2	0.1	0	0	0	0	0
Silver hake	Merluccius bilinearis	0	0	0	0	0.1	0	0	0	0	0	0
Pollock	Pollachius virens	0	0	0.05	0	0	0	0	0	0	0	0
Hake	Urophycis spp.	0	0	0	0	1.6	0.3	3.5	0.1	0	0	0
Wrasses-Yellowtail flounder	Labridae-Limanda	*	*	*	46.9	266.7	204.3	52.1	2.5	0	0	0
Wrasses	Labridae	0	0	0	0.3	81.8	5.9	10.2	0.6	0	0	0
Atlantic mackerel	Scomber scombrus	0	0	0	0.2	73.0	0	0	0	0	0	0
Butterfish	Peprilus triacanthus	0	0	0	0	0	0	4.6	0	0	0	0
Windowpane	Scophthalmus aquosus	0	0	0.3**	-	-	-	-	-	0	0	0
Fourspot flounder-Windowpane	Paralichthys-Scophthalmus	*	*	*	132.4	86.7	24.3	32.9	31.4	0.2	0	0
Witch flounder	Glyptocepahlus cynoglossus	0	0	0	0.4	0.9	0.1	0.1	0.1	0	0	0
American plaice	Hippoglossoides platessoides	0	6.3	8.4	4.8	0.1	0.1	0	0	0	0	0
Yellowtail flounder	Limanda ferruginea	0	0	5.1**	2.3	5.6	0.1	0	0	0	0	0
Winter flounder	Pseudopleuronectes americanus	0	1.2	0.6	0	0	0	0	0	0	0	0
Total Eggs		0.1	12.5	16.7	194.9	526.4	241.0	111.5	35.4	3.4	11.1	7.4

*Groupings were not necessary during these months - see methods.

**Represents all three egg stages since other species with which these eggs may be grouped had not begun to spawn.

NOTE: Sampling scheduled for January 1985 could not be conducted due to ice.

Table K37 (continued).

Species		Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
LARVAE												
American eel	_Anguilla rostrata_	0	0	0.1	0.07	0	0	0	0	0	0	0
Atlantic menhaden	_Brevoortia tyrannus_	0	0	0	0	0.1	0.1	0	0	0	0	0
Atlantic herring	_Clupea harengus harengus_	0	0.2	1.4	0	0	0	0	0	0.1	18.6	2.8
Anchovy	_Anchoa_ spp.	0	0	0	0	0	0	0	0.3	0	0	0
Rainbow smelt	_Osmerus mordax_	0	0	10.0	5.4	0	0	0	0	0	0	0
Goosefish	_Lophius americanus_	0	0	0	0	0	0	0.1	0.7	0	0	0
Fourbeard rockling	_Enchelyopus cimbrius_	0	0	0	0	8.1	0.1	0.2	0.2	0	0	0
Atlantic cod	_Gadus morhua_	0.4	0	0	0.1	0	0	0	0	0	0	0
Silver hake	_Merluccius bilinearis_	0	0	0	0	0.1	0	0	0.1	0	0	0
Pollock	_Pollachius virens_	0	0	0	0	0	0	0	0	0	0	0.1
Hake	_Urophycis_ spp.	0	0	0	0	0	0.1	0.2	0	0	0	0
Silverside	_Menidia_ spp.	0	0	0	0	2.3	0.4	0.4	0	0	0	0
Threespine stickleback	_Gasterosteus aculeatus_	0	0	0	0	0.1	0	0	0			
Northern pipefish	_Syngnathus fuscus_	0	0	0.05	0	1.4	2.8	2.3	0.6	0.4	0.1	0
Tautog	_Tautoga onitis_	0	0	0	0	0.1	0	0.4	0.1	0	0	0
Cunner	_Tautogolabrus adspersus_	0	0	0	0	5.2	0.2	6.8	0	0	0	0
Radiated shanny	_Ulvaria subbifurcata_	0	0	0.3	10.7	9.5	1.3	0.	0	0	0	0
Rock gunnel	_Pholis gunnellus_	0	25.7	6.2	0.1	0	0	0	0	0	0	0
Sand lance	_Ammodytes_ sp.	0	13.2	152.6	11.7	0.1	0	0	0	0	0	0
Atlantic mackerel	_Scomber scombrus_	0	0	0	0	7.2	0.1	0	0	0	0	0
Butterfish	_Peprilus triacanthus_	0	0	0	0	0	0	0	0	0.1	0	0
Grubby	_Myoxocephalus aenaeus_	0	7.8	3.7	0.3	0	0	0	0	0	0	0
Longhorn sculpin	_M. octodecemspinosus_	0	0.3	0	0	0	0	0	0	0	0	0
Shorthorn sculpin	_M. scorpius_	0	0.2	0	0	0	0	0	0	0	0	0

Table K37(continued).

Species		Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
LARVAE												
Seasnail	*Liparis americanus*	0	0	1.0	0.3	0	0	0	0	0	0	0
Gulf snailfish	*L. coheni*	0	0.2	0	0	0	0	0	0	0	0	0
Windowpane	*Scophthalmus aquosus*	0	0	0	0	1.7	0.1	0.6	0.4	0	0	0
Witch flounder	*Glyptocephalus cynoglossus*	0	0	0	0	0.4	0	0	0	0	0	0
American plaice	*Hippoglossoides platessoides*	0	0.1	0.9	0.8	0.5	0.1	0.1	0	0	0	0
Yellowtail flounder	*Limanda ferruginea*	0	0	0	0.5	0.6	0	0	0	0	0	0
Smooth flounder	*Liopsetta putnami*	0	0	0.1	0	0	0	0	0	0	0	0
Winter flounder	*Pseudopleuronectes americanus*	0	0	10.8	61.9	0.1	0	0	0	0	0	0
Total Larvae		0.4	47.7	187.1	91.9	37.2	5.0	11.1	2.3	0.6	18.7	3.0

offshore during the summer months and transported by currents into the river. Juveniles of these species probably depart the estuary in the fall.

Silversides probably spawn demersal eggs in the Saugus River. Else-where, spawning typically occurs in May (Leim and Scott, 1966). Larvae were noted during June through August. The threespine stickleback is a nest builder and spawns only in freshwater during June and July. The appearance of larvae at Station C indicates that this species utilizes the upper reaches of the Saugus River.

The ubiquitous presence of northern pipefish larvae from June through November indicates that the estuary may be an important nursery area for the species. Eggs are absent from the ichthyoplankton collections since the male carries the fertilized eggs in a brood pouch until hatching (Leim and Scott, 1966). Spawning is known to occur during June and July in Long Island Sound. A similar spawning period is likely to occur in the Saugus and Pines Rivers Estuary.

Tautog (Labridae), cunner (Labridae), windowpane and mackerel eggs accounted for over 95% of the eggs collected in June. It is likely that these eggs were spawned in nearshore coastal waters and transported into the estuary. Estuary spawning by these species has not been documented. Tautog eggs are probably more abundant in the samples identified as Labridae in May and June while cunner eggs dominate the Labridae samples in August and September. This would agree with the known spawning periods of these species (Leim and Scott, 1966). Atlantic mackerel eggs appearing in the May and June samples were probably spawned in Massachusetts Bay which is regarded as one of the most important spawning grounds for the species (Leim and Scott, 1966).

The occurrence of radiated shanny larvae in the April and May samples is unusual since the species is thought to spawn during the summer (Leim and Scott, 1966). It is not known if radiated shanny spawns in the estuary.

Rock gunnel, sand lance, and sculpins (Myoxocephalus spp.) spawn demersal, adhesive eggs in nearshore coastal waters during the winter. Larvae are transported into the estuary by tidal currents. The grubby (a sculpin) is a resident estuarine species (Leim and Scott, 1966) and may spawn in the estuary.

Winter flounder spawn within the estuary. Winter flounder spawn demersal eggs on sandy bottoms, often in water depths as shallow as 6 ft (Thomson et al., 1971). Primary period for spawning in the Saugus/Pines Estuary is probably March and April and utilization of the estuary as a nursery area extends into the summer.

The buoyant eggs of windowpane flounder (Scophthalmus aquosus), witch flounder (Clyptocephalus cynoglossus), plaice (Hippoglossoides platessoides) and yellowtail (Limanda femuginea) found during the sampling were probably spawned in nearshore coastal waters and transported into the Saugus River. Smooth flounder (Liopsetta putnami) is considered an estuarine species and probably spawns in the estuary in late winter or early spring.

Among flounders, larvae of winter flounder were most abundant, followed by windowpane, plaice, witch flounder and smooth flounder (Liopsetta putnami).

Adult Fish

Existing Resources

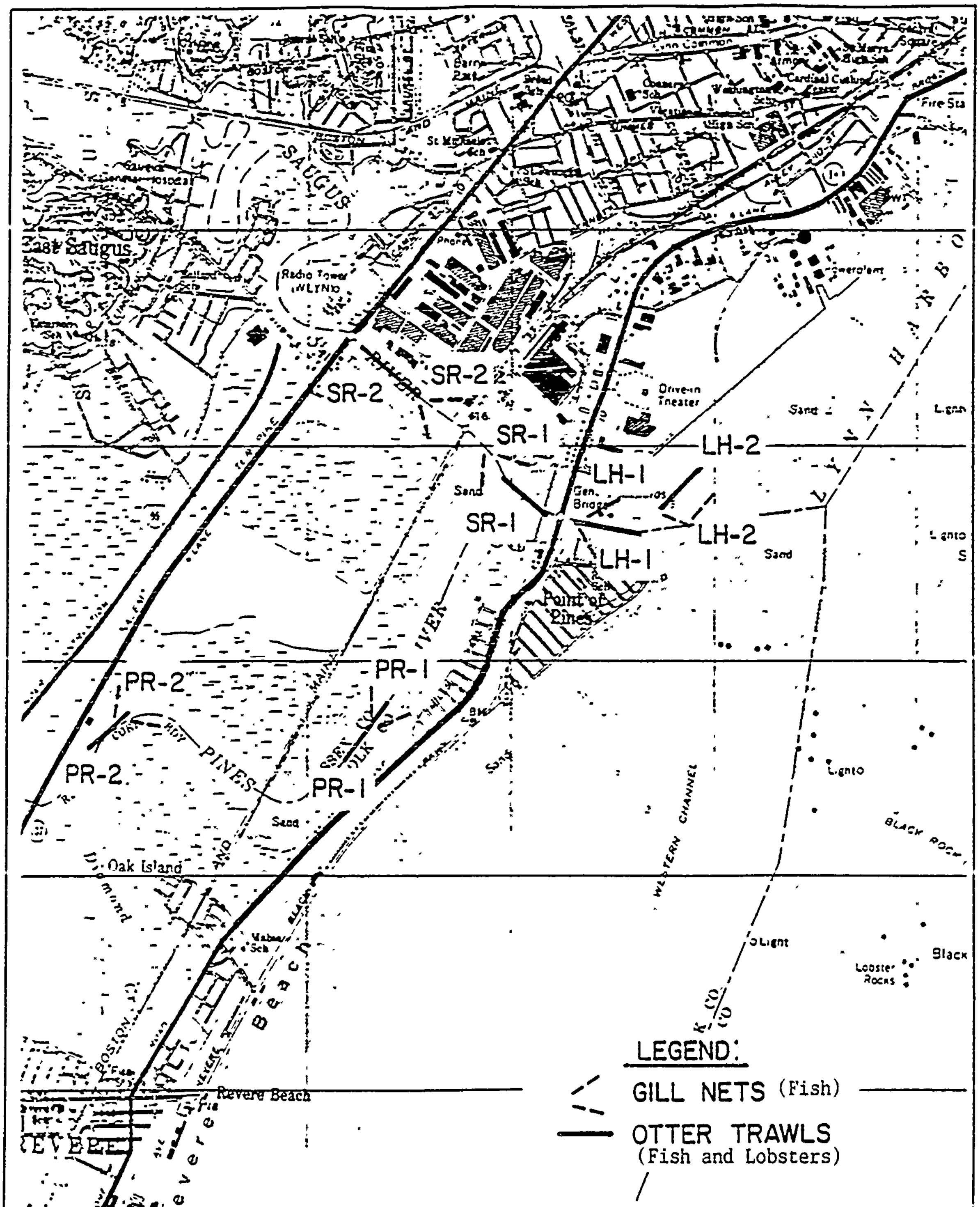
Information concerning the adult fish inhabiting the Saugus River Estuary and Lynn Harbor is available from previous studies (Chesmore et al., 1972; Raytheon, 1974 and MRI, 1985) and the current investigation. The Chesmore et al. (1972) study used haul seines and a shrimp trawl. Sampling stations were located in Lynn Harbor (off Nahant and Revere) and in the lower Saugus and Pines Rivers (below the Route 107 overpass). The Raytheon (1974) study utilized beach seines, bottom trawls and gill nets. Sampling stations were located in Lynn Harbor, the lower Saugus River (at the confluence with the Pines) and in Nahant Bay. MRI (1985) utilized otter trawls and beach seines. Sampling stations were located in the Pines River (near its confluence with the Saugus) and at several points in the Saugus River ranging from near the Saugus General Hospital to the confluence with the Pines.

The current study utilized otter trawls and gill nets. Samples were collected in July and October of 1987. A 20-foot otter trawl with a 0.5" mesh cod end liner was used to sample the demersal fish population. Gill nets with variable stretched net mesh (1", 2", 4" and 6") were deployed at the beginning of a tidal cycle and retrieved six hours later at the end of the tidal cycle to assess pelagic fish communities. Both sampling methods were performed at six permanent stations. Station locations are shown in Figure K26.

All fish collected were identified to species, measured for standard length (mm) and weighed (g) on board the sampling vessel. All fish were examined externally for evidence of parasites, tumors, fin rot or other infections; no observable diseases were detected. Any crabs and lobsters collected were also enumerated. Lobsters, which are discussed later were measured for carapace length (mm) and weighed (g).

A checklist of the adult finfishes occurring in the Saugus and Pines Rivers Estuary and Lynn Harbor in the previous studies as well as the current study is provided in Table K38. Overall 38 species were noted. Species of commercial and recreational value commonly occurring in the estuary included Atlantic herring, Atlantic tomcod, Atlantic cod, the hakes, bluefish and the flounders. Also noted were five species of anadromous fish: alewife, blueback herring, American shad, rainbow smelt and brown trout. The first four spawn in the upper reaches of the Saugus and Pines Rivers. The stocked brown trout may spawn there. The important anadromous fish runs occur in the spring (April through June).

Winter flounder was identified as the most common species in all three previous studies. Seasonal changes in finfish abundance in the estuary and Lynn Harbor were evident. The Chesmore et al. (1972) and MRI (1985) studies found that winter flounder were most abundant in the Saugus and Pines Rivers from March



SCALE: 1"= 2083'

SAUGUS / PINES RIVERS ESTUARINE WETLANDS STUDY

FISH AND LOBSTER STATIONS*

Figure K26

*See Figure K27 for Lobster Sets.

Table K38. Fishes recorded from the Saugus/Pines Rivers Estuary and Lynn Harbor in contemporary studies. Collections made by otter trawl, beach seines and gill nets.

Species: Common Name[1]	Species: Scientific Name	Chesmore *et al.* 1972	Raytheon[2] 1974	MRI 1985	This Study IEP 1988
American Eel (c)	*Anguilla rostrata*	X		X	
Atlantic Herring	*Clupea harengus harengus*	X		X	X
Alewife (a)	*Alosa pseudoharengus*	X		X	X
Blueback Herring (a)	*Alosa aestivalis*	X		X	X
American Shad (a)	*Alosa sapidissima*			X	
Atlantic Menhaden (s)	*Brevoortia tyrannus*			X	X
Rainbow Smelt (a)	*Osmerus mordax*	X	X	X	
Bay Anchovy	*Anchoa mitchilli*			X	
Atlantic Silverside	*Menidia menidia*	X	X	X	
Inland Silverside	*Menidia beryllina*			X	
Mummichog	*Fundulus heteroclitus*	X			
Striped Killifish	*Fundulus majalis*	X	X		
Threespine Stickleback	*Gasterosteus aculeatus*	X	X	X	
Fourspine Stickleback	*Apeltes quadracus*	X	X		
Ninespine Stickleback	*Pungitius pungitius*	X			
American Sand Lance	*Ammodytes americanus*	X			
Atlantic Tomcod	*Microgadus tomcod*	X	X		
Atlantic Cod	*Gadus morhua*		X	X	
Silver Hake (or Whiting) (s)	*Merluccius bilinearis*		X		
Red Hake (s)	*Urophycis chuss*	X	X		X
Ocean Pout	*Macrozoarces americanus*		X		
White Hake (s)	*Urophycis tenuis*			X	
Northern Pipefish	*Syngnathus fuscus*	X	X	X	X
Cunner	*Tautogolabrus adspersus*		X	X	X
Bluefish (s)	*Pomatomus saltatrix*			X	X
Little Skate	*Raja erinacea*		X		
Skate	*Raja* spp.	X		X	X
Grubby	*Myoxocephalus geneus*	X		X	X
Longhorn Sculpin	*Myoxocephalus octodecemspinosus*	X	X		X
Shorthorn Sculpin	*Myoxocephalus scorpius*	X			
Winter Flounder	*Pseudopleuronectes americanus*	X	X	X	X
Yellowtail Flounder	*Limanda ferruginea*		X	X	
Smooth Flounder	*Liopsetta putnami*			X	
Summer Flounder	*Paralichthys dentatus*			X	X
Windowpane Flounder	*Scopthalmus aquosus*		X	X	X
Striped Bass (s)	*Morone saxatilis*				X3
Pollock	*Pollachius virens*				X3
Atlantic Mackerel (s)	*Scomber scombrus*				X3
Brown Trout (a)	*Salmo trutta*				X4
TOTAL NUMBER OF SPECIES		20	17	23	18

Notes: 1. c: catadromous
a: anadromous
s: seasonal migrant

2. Commonly occurring in Lynn Harbor or near the mouth of the Saugus River.
3. Noted from IEP's recreational fishery surveys.
4. Stocked by sportsmen's clubs and the Massachusetts Division of Fisheries and Wildlife.

through July and in the fall (October or November); spawning probably takes place primarily during March and April and utilization of the estuary as a nursery area extends into the summer. Few winter flounder or other fish were captured from the estuary during January and February.

The Raytheon (1974) studies generally captured few fish from Lynn Harbor during winter months when temperatures were low. Demersal fish showed evidence of seasonal peaks in the fall, while pelagic species were most abundant in early summer (June - July). Finfish collected in beach seines (principally Atlantic silversides amd striped killifish) were most abundant during the fall (September through November), with minimum abundance occurring in winter and early spring.

Tables K39 and K40 summarize the otter trawl and gill net collections made during the current study. The species encountered varied with the sampling date, but five species (winter flounder, windowpane flounder, grubby, cunner and little skate) occurred both in July and October. As in previous studies of the estuary (Chesmore et al., 1972; MRI, 1985) and Lynn Harbor (Raytheon, 1974), winter flounder was the dominant fish species found. In general, this species was distributed throughout the estuary, and collected at most sampling stations.

Catch per unit effort (CPUE) in October otter trawls (Table K42) was approximately twice that of those in July (Table K41) (excluding one trawl in which a school of herring was encountered). Gill net CPUE was also greater in October (Table K44) than in July (Table K43) (IEP, Inc., 1988).

Recreational Fisheries

Winter flounder supports an important recreational fishery. The season starts in April and continues into fall, with the best catches occurring in April (HMM Associates, 1986). Other popular species fished from the shoreline and bridges include striped bass (April - June), bluefish (June - August) and pollock (late June). Anadromous species are targeted either during spring (alewife and blueback herring) or fall (rainbow smelt) runs. During the winter the Sea Plane Basin area of the estuary is a popular location for fishing for mackerel, small Atlantic cod and American eel (Anguilla rostrata).

Biology of Important Species

This section provides life history information concerning twelve species of fish which inhabit the estuary. Those chosen for review are considered to be of particular importance to the recreational fishery. Information provided by these life histories will aid in the assessment of the potential effects of the proposed plans on these important fish species. Reference sources for species life histories include Leim and Scott (1966), Breder (1948), Thompson et al., (1971), Scott and Crossman (1973), Clayton et al., (1978) and Bell (1986).

Table K39. July 1987 Saugus/Pines Rivers Estuary Otter Trawl (OT) and Gill Net (GN) Collections.

SPECIES		STATION													
Common Name	Scientific Name	SR1		SR2		PR1		PR2		LH1		LH2		TOTAL	
		OT	GN	OT	GN	OT	GN	OT	GN	OT	GN	OT	GN	OT	GN
Winter Flounder	<u>Pseudopleuronectes americanus</u>	19		10		6		6		10	1	2		53	1
Summer Flounder	<u>Paralichthys dentatus</u>			2				3					1	5	1
Windowpane Flounder	<u>Scophthalmus aquosus</u>	1								2		2	2	5	2
Atlantic Herring	<u>Clupea harengus harengus</u>											136		136	0
Blueback Herring	<u>Alosa aestivalis</u>										1			0	1
Grubby	<u>Myoxocephalus aengeus</u>									2				2	0
Cunner	<u>Tautogolabrus adspersus</u>								4					0	4
Bluefish	<u>Pomatomus saltatrix</u>				1									0	1
Little Skate	<u>Raja erinacea</u>	1								2				3	0
Squid	<u>Loligo</u> sp.	4												4	0
Mud Crab	<u>Carcinus maenus</u>	55		172		256		159		28		202		872	0
Rock Crab	<u>Cancer</u> spp.	119		6		13		6		35		4		183	0
Spider Crab	<u>Libinia</u> sp.		1											0	1
Horseshoe Crab	<u>Limulus polyphemus</u>			1	2	2		1						4	2
Lobster	<u>Homarus americanus</u>	3		8						2		1		14	0

Table K40. October 1987 Saugus/Pines Rivers Estuary Otter Trawl (OT) and Gill Net (GN) Collections.

SPECIES		STATION													
Common Name	Scientific Name	SR1		SR2		PR1		PR2		LH1		LH2		TOTAL	
		OT	GN	OT	GN	OT	GN	OT	GN	OT	GN	OT	GN	OT	GN
Winter Flounder	*Pseudopleuronectes americanus*	28	3	9		15	6	31	1	4		18		105	10
Windowpane Flounder	*Scophthalmus aquosus*	6		16		4		3		1	2	1		31	2
Atlantic Menhaden	*Brevoortia tyrannus*				1									0	1
Alewife	*Alosa pseudoharengus*							1						1	0
Grubby	*Myoxocephalus aengeus*			1						1				2	0
Longhorn Sculpin	*Myoxocephalus octodecemspinosus*							1						0 1	0 0
Cunner	*Tautogolabrus adspersus*								1					0	1
Northern Pipefish	*Syngnathus Fuscus*									1				1	0
Red Hake	*Urophycis chuss*									1				1	0
Little Skate	*Raja erinacea*	2		1				2						5	0
Big Skate	*Raja ocellata*											1		1	0
Mud Crab	*Carcinus maenus*	159		606		45		310		21		392		1533	0
Rock Crab	*Cancer* spp.	164		43		12		43		41		3		306	0
Spider Crab	*Libinia* sp.						1							0	1
Horseshoe Crab	*Limulus polyphemus*			3				2						5	0
Lady Crab	*Ovalipes ocellatus*			1		1		15						17	0
Lobster	*Homarus americanus*	2		4				1		1				8	0

Table K41. July 1987 Otter Trawl Catch Per Unit Effort

Station	Depth	Trawl	No. of Fish/CPUE	Fish Biomass/CPUE
SR1	7 m	A	12/2.4	1089g/217.8
	6 m	B	8/1.6	664g/132.8
SR2	3 m	A	11/2.2	1158g/231.6
	3 m	B	1/0.2	11.5g/2.3
PR1	3 m	A	3/0.6	71.5g/14.3
	3 m	B	3/0.6	117.5g/23.5
PR2	3 m	A	5/1.0	393.5g/78.7
	3 m	B	4/0.8	1076.5g/215.3
LH1	6 m	A	9/1.8	639g/127.8
	7 m	B	4/0.8	548.5g/109.7
LH2	3 m	A	138/27.6	247g/49.4
	3 m	B (2)	2/0.4	700g/140

Unit effort = 5 minute tow

Table K42. October 1987 Otter Trawl Catch Per Unit Effort

Station	Depth	Trawl	No. of Fish/CPUE	Fish Biomass/CPUE
SR1	10 m	A	17/3.4	2969g/593.8
	10 m	B	19/3.8	2584g/516.8
SR2	7 m	A	8/1.6	893.5g/178.7
	7 m	B	16/3.2	155g/31.0
PR1	3 m	A	7/1.4	558g/111.6
	3 m	B	12/2.4	3225g/645
PR2	3 m	A	18/3.6	2629.5g/525.9
	3 m	B	19/3.8	596g/119.2
LH1	10 m	A	5/1.0	347g/69.4
	10 m	B	3/0.6	18g/3.6
LH2	5 m	A	6/1.2	877.9g/175.6
	5 m	B	14/2.8	95g/19.0

Unit effort = 5 minute tow

Table K43. July 1987 Gill Net Catch Per Unit Effort

Station	Depth	Set	No. of Fish/CPUE	Fish Biomass/CPUE
SR1	2 m	A	0/0	0/0
	2 m	B	0/0	0/0
SR2	7 m	A	1/0.2	13.5g/2.2
	2 m	B	0/0	0/0
PR1	3 m	A	0/0	0/0
	3 m	B	0/0	0/0
PR2	3 m	A	4/0.7	47g/7.8
	3 m	B	0/0	0/0
LH1	4 m	A	1/0.2	150g/25.0
	4 m	B	1/0.2	29.5g/4.9
LH2	3 m	A	0/0	0/0
	3 m	B	2/0.3	800g/133.3

Unit effort = 6 hour set

Table K44. October 1987 Gill Net Catch Per Unit Effort

Station	Depth	Set	No. of Fish/CPUE	Fish Biomass/CPUE
SR1	4 m	A	3/0.5	3375g/562.5
	4 m	B	0/0	0/0
SR2	5 m	A	1/0.2	235g/39.2
	5 m	B	0/0	0/0
PR1	3 m	A	4/0.7	3775g/629.2
	3 m	B	1/0.2	7g/1.2
PR2	4 m	A	2/0.3	25g/4.2
	4 m	B	0/0	0/0
LH1	4 m	A	2/0.3	895g/149.2
	4 m	B	0/0	0/0
LH2	4 m	A	0/0	0/0
	4 m	B	0/0	0/0

Unit effort = 6 hour set

Winter Flounder (Psuedopleuronectes americanus)

Spawning occurs in the late winter to spring in shallow water on soft muddy to moderately hard substrates. Eggs are demersal and adhesive. Average fecundity is 500,000 eggs. In 40° F water, eggs hatch in 26 days while at 60° F, hatching occurs in 18 days. Preferred water temperatures for adults range from 53-60° F. Winter flounder can tolerate wide temperature ranges and low salinities. Typically, there is a seasonal migration where the species moves into deeper waters in the summer and then returns to inshore areas during the winter. Diet includes amphipods, isopods, and marine worms (Nereis). Soft shell clams (Mya) and other small bivalves are also eaten along with snail eggs and seaweed. Maximum size is 18 inches which corresponds to about 8 years of age. Two year olds average 7 inches.

Striped Bass (Morone saxatilis)

Evidence of spawning by this species in Massachusetts waters has not been reported in recent years. Elsewhere spawning occurs in late spring (April - June) at the head of tidal influence in estuaries. Eggs are neutrally buoyant and nonadhesive. Fecundity varies from 11,000 eggs to several million. Eggs hatch in three days in water temperatures of 58-60° F and in two days at 67° F. For optimum development, water currents should be sufficient to prevent the eggs from settling to the bottom where they may be silted over and suffocate. Preferred temperatures range from 60-65° F. Juvenile striped bass diet consists of sand shrimp. Adults forage on small fishes and invertebrates including sea worms, amphipods, and squid. Juveniles fall prey to silver hake and cod while adults have few predators. Age at sexual maturity is 5 years for females and 2 years for males. Migration to sea occurs at the age of 2. Bass usually spend less than one year in the open sea.

Rainbow Smelt (Osmerus mordax)

Rainbow smelt spawn at the head of the tide in estuaries and also in streams and brooks. Smelt enter estuaries in the fall and spawn, typically at night, from April through June. Eggs are adhesive and attach to rocks, gravel and vegetation. Fecundity ranges from 7000 to 60,000 eggs per female. In 39° F water, eggs hatch in 51-63 days, 53° F in 16-21 days, and in 8-10 days in water temperatures of 68° F. Larvae are 5mm long at hatching. The juvenile diet consists of copepods and other plankton. Adults subsist on amphipods, euphasids, mysids, shrimp, and Nereis. Small fish such as herring, mummichogs and silversides are also important prey items in the adult diet. Smelt predators include cod, salmon, other large fish and birds. This anadromous species often aggregates in schools. They are sensitive to light and are often found along the bottom during daylight hours. Average size is 8 inches with a life span of five years.

Alewife (Alosa pseudoharengus)

Alewife spawn at night above the tidal influence in ponds and rivers during April and May. Spawning occurs over sandy or gravelly bottoms. Eggs are demersal and somewhat adhesive. Female fecundity ranges from 60,000

to 100,000 eggs. Adult alewives depart spawning grounds for the sea by July. Juveniles migrate in September. Preferred spawning temperatures range from 48-54° F. Eggs hatch in six days in water temperatures of 60° F and in three days at 72° F. It is believed that alewives may be sensitive to abrupt changes in temperature. Diet consists of plankton including amphipods, mysids, and copepods. At the age of three alewives are sexually mature. They are an important forage species for larger piscivorous fishes and eels. Alewives display inshore movements during the night and offshore movements during daylight hours.

Blueback Herring (Alosa aestivalis)

The life history of the blueback herring closely parallels that of the alewife. However, spawning occurs in June and in areas more brackish than that used by the alewife. Eggs are demersal and adhesive. Hatching occurs in 2-3 days in water temperatures of 22.2-23.9° C (72-75° F). After completing spawning the adults return to sea. Juveniles migrate seaward at one month when they are 30-50mm long. Normal size range is 380mm (15in) and a weight of 13oz. Diet includes plankton, copepods, pelagic shrimp, small fish fry, fish eggs and larvae.

Sea Run Brown Trout (Salmo trutta)

The brown trout tolerates a wider range of environmental conditions than any other salmonid. Spawning occurs during late autumn and early winter in the shallow, gravelly headwaters of estuaries. The female constructs a nest (redd) in the gravel during the fall and early winter in which eggs and sperm are deposited. The redd is then covered by the female with gravel. Fecundity for five to six year old females averages 2000 eggs. Preferred spawning temperatures range from 6.7-8.9° C (44-48° F). Optimum adult temperatures range from 18.3-23.9° C (65-75° F). Age at sexual maturity is 3-4 years. The species is carnivorous, preying on insects and larvae, crustaceans and fishes.

Atlantic Cod (Gadus morhua)

The spawning period for cod is highly varied but appears to extend from October through April. Principal spawning grounds are located offshore. Fecundity ranges from 5-8 million eggs. The buoyant eggs hatch in 17 days at a water temperature of 40° F. Preferred temperatures for adults range from 31-50° F. Upper water temperature boundary is 66° F. Cod display a tendency to move inshore in the spring and summer and offshore in the winter. Cod fry subsist on copepods, barnacle larvae, amphipods and small crustaceans. Fish larger than 20in forage on herring, sand lance and other fishes. Life span is documented to 16 years.

Atlantic Haddock (Melanogrammus aeglefinus)

Inshore spawning of this species is considered minimal. Spawning primarily occurs from January through July in the offshore banks. Fecundity ranges from 169,000 to 2 million eggs. Buoyant eggs are pelagic for two or more weeks. Haddock larvae exist in a pelagic state for approximately

three months. Eggs hatch in 25-32 days in water temperatures of 36° F, 13-24 days at 41° F and in 9-12 days in 50° F water. Preferred rearing temperatures range from 36-54° F. Optimum adult temperatures are 35-48° F. Preferred adult habitat includes deepwater channels where fish are closely associated with the bottom. Haddock are tolerant to wide salinity ranges, i.e. 15-35 ppt. Prey items include invertebrates, especially brittle stars and bivalves. Sand lance are also an important dietary staple. Adult and smolt haddock also prey on cod, pollock and hake. Normal size ranges from 15-25in and 1-4lb.

Atlantic Pollock (*Pollachius virens*)

Spawning occurs during November through January. Fecundity averages 220,000 eggs. The buoyant eggs hatch in nine days at 43° F and in six days at 49° F. Pollock become sexually mature at three years of age. Normal size range is 7-10lb. Inshore foraging is on small crustaceans, primarily amphipods and euphausids. The offshore diet consists of fishes, with sand lance being the dominant prey item.

Atlantic Mackerel (*Scomber scombrus*)

Spawning occurs during May through July when water temperatures exceed 46° F. Fecundity averages 41,000 eggs. The buoyant eggs hatch in two days at 70° F and in nine days at 50° F. Diet consists nearly exclusively of zooplankton with Calanus, pelagic amphipods, euphausids, fish eggs and larvae of herring, silversides and sand lance being important constituents. Mackerel are one of the most active and migratory of the pelagic species and demonstrate a general onshore movement during the spring. The species is known to aggregate into large schools.

Bluefish (*Pomatomus saltatrix*)

Bluefish spawn buoyant eggs offshore during June through August. Preferred summer water temperature for adults is 58° F. Bluefish form schooling aggregations where they are voracious feeders on schools of mackerel, herring. menhaden and alewives. Normal size range is 10-15lb.

American Eel (*Anguilla rostrata*)

Spawning occurs at sea. Juveniles (elvers), which are one year old and about 60-65mm (2.5in) in length, enter estuarine areas during May and June to continue upstream migrations to freshwater where they inhabit muddy, silty bottoms. Diet consists of small fishes, invertebrates and insect larvae. Young alewives are known to be an important prey species. Sexually mature adults initiate a downstream migration in the fall to spawning areas in the Saragasso Sea.

Summary

The finfish of the Saugus/Pines Rivers Estuary and Lynn Harbor have been and continue to be an important natural resource to the area. Exploited initially by subsistence level and commercial harvesting, the existing finfish resources are utilized primarily by recreational sportsmen.

Contemporary field studies indicate that adults of at least 38 species of fish inhabit the estuary and/or Lynn Harbor. About one-third of these are seasonal migrants, catadromous or anadromous species which are likely to be common in the estuary only during part of the year. An additional 13 species are represented solely in the ichtyoplankton. Winter flounder is the most abundant resident species among those of recreational or potential commercial importance.

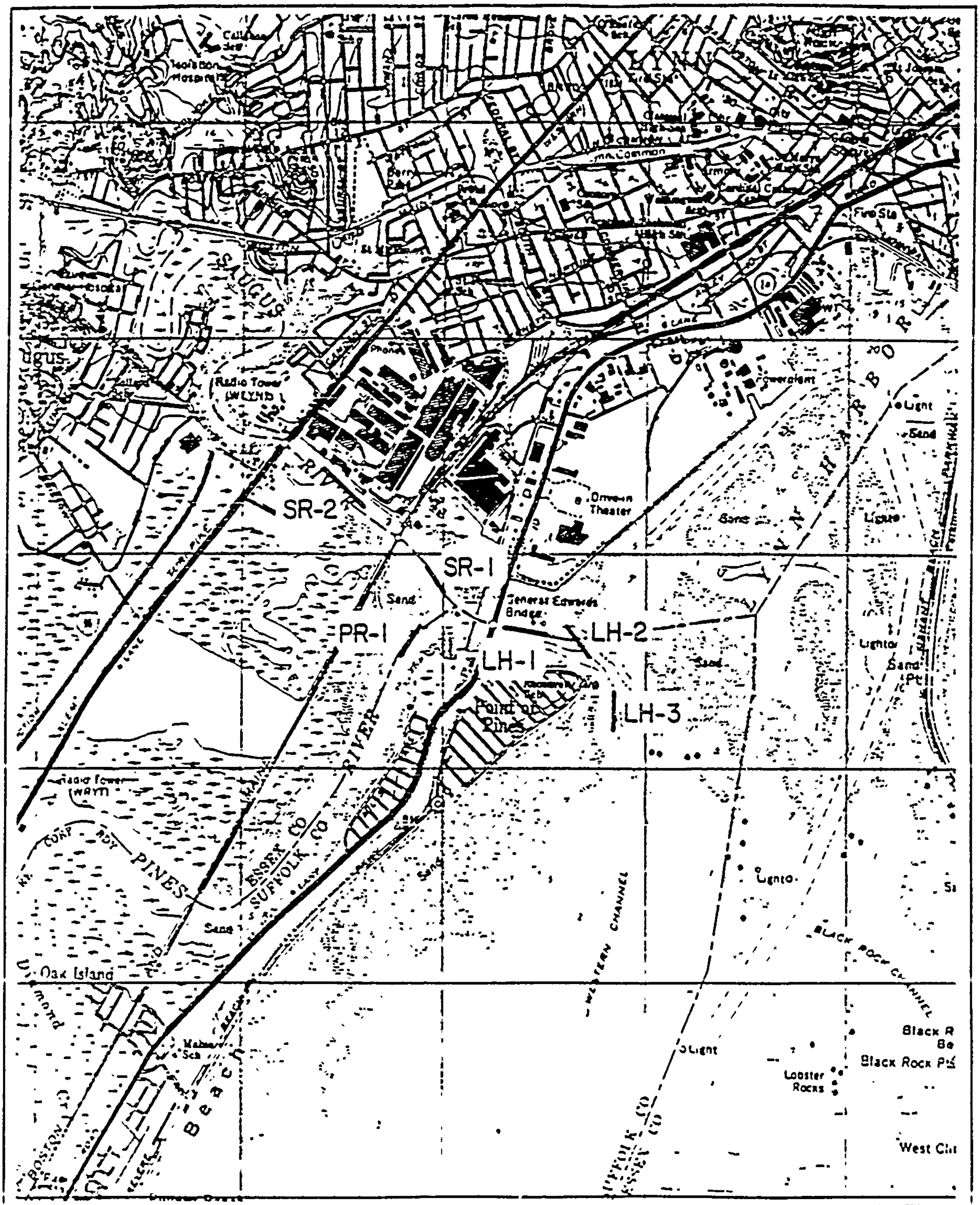
The MRI (1985) ichthyoplankton study documented the significance of the Saugus/Pines Rivers Estuary as a spawning ground and/or nursery for numerous fish, including commercially and recreationally important species such as flounders, cod and mackerel. Planktonic larvae are most abundant during April (fairly high larval densities extended from March into June); eggs are most abundant during June (fairly high egg densities extended from May into mid summer); a much lower secondary peak in larval abundance occurred in the late fall.

Many of the species that were identified in the Study Area are known to spawn in the nearshore waters of Massachusetts Bay. Pelagic eggs and larvae of these species are transported into the estuary under the influence of tidal currents. Within the estuary, eggs hatch and further larval development occurs. In early spring and fall the planktonic larval community is dominated by species which spawn outside the estuary.

N. Lobsters

Historical and Existing Conditions

Little is known concerning the abundance and distribution of lobsters (*Homarus americanus*) in the Saugus/Pines Rivers Estuary and Lynn Harbor. Because lobsters occur infrequently at salinities below 25-29 ppt (B. Estrella, Mass. Div. of Marine Fisheries, 1988 - Personal Communication), however, it is likely that few are found in the upper reaches of the Saugus River. None are likely to occur where salinities drop below 8 ppt (Cobb, 1976). Lobsters may occur in the upper reaches of the Pines River because there is little freshwater inflow and salinities remain high. Bottom trawls conducted during 1970-1974 (Raytheon, 1974) captured a few lobsters in the lower Saugus River (near the confluence with the Pines River) and in Lynn Harbor. Sampling conducted for this study using otter trawls (see Figure K26 for locations) and lobster traps (see Figure K27 for locations) captured lobsters from the Saugus and Pines Rivers (downstream of the Highway 107 overpasses) and from Lynn Harbor (off Point of Pines and in the vicinity of alternative floodgate Alignments 1, 2 and 3). The resulting data is presented in Table K45. Lobsters were most abundant at stations in the Saugus River. Lobster density in the vicinity of the proposed floodgate (Lynn Harbor Stations 1 & 2) does not appear to be high. An average of about 0.5 lobsters per trap was caught in traps deployed for 24 hours near Alignments 1, 2 and 3. Lobsters caught in the Saugus and Pines Rivers ranged in length from 30 to 119mm (mean = 63mm, n = 37). Those caught in Lynn Harbor ranged in length from 56 to 100mm (mean = 75mm, n = 11).



SCALE: 1" = 2083'	SAUGUS / PINES RIVERS ESTUARINE WETLANDS STUDY	LOBSTER SETS *	Figure K27

*See Figure K26 for Otter Trawls.

Table K45. Summary of Lobsters Caught in Otter Trawls and Lobster Traps.

Location[3]	Otter Trawls[1]		Lobster Traps[2,4]
	July 87	October 87	July 87
Saugus River			
Station 1	3	2	12
Station 2	8	4	1
Pines River			
Station 1	0	0	6
Station 2	0	1	-
Lynn Harbor			
Station 1	2	1	1
Station 2	1	0	2
Station 3	-	-	5

Notes:

1. See Figure K26 for otter trawls locations.

2. See Figure K27 for lobster traps locations.

3. Note that otter trawls and lobster traps stations were at somewhat different locations, in some cases.

4. Total number of lobsters caught in three traps deployed at each location for 24 hours.

No significant commercial lobster fishery exists in the Saugus/Pines Estuary or Lynn Harbor (B. Estrella, Mass. Div. of Marine Fisheries, 1988 - Personal Communication). Although large numbers of lobsters have been landed at the Lynn-Saugus Harbor (Chesmore et al., 1972), most of these lobsters were apparently captured in waters outside the Saugus/Pines Estuary and Lynn Harbor. In the 1987 studies for this report, approximately 80% of the lobsters captured within the estuary, and 65% of those from Lynn Harbor, were smaller than the Massachusetts minimum size limit for legal harvest (81mm).

Lobsters inhabiting the Saugus/Pines Estuary probably exhibit some degree of movement from shallow inshore waters in summer to deeper offshore waters in winter. Most lobsters collected in bottom trawls by Raytheon (1974) from Lynn Harbor, the mouth of the Saugus River and Nahant Bay were captured between May and October.

O. Wildlife

Marine Mammals

A letter dated July 10, 1987 from the Oak Island Residents Association, an organization formed primarily to help protect the salt marsh and wetlands in Revere and Saugus, describes occasional use of the Saugus River by the Harbor Seal (*Phoca vitulina*). The National Marine Fisheries Service estimates 2,000 - 3,000 Harbor Seals (primarily juveniles) overwinter in the Cape Cod area (Beach, 1988). The present breeding range of the Harbor Seal extends from the ice-free waters of the Arctic through Maine. Harbor Seals, now only seasonal residents of Massachusetts, can be found in harbors feeding on anadromous fish, shellfish and squid from late September to late May (SES, 1986). Harbor Seal bounties (in existence until 1962 in Massachusetts) undoubtedly resulted in overall reduction in seal numbers in southern New England and likely led to the extirpation of breeding activities south of Maine (SES, 1986).

In addition, the White-sided Dolphin (*Lagenorhynchus acutus*) might be seen close to shore feeding on migratory fish in the late fall/early winter. This species is a year round resident of Massachusetts Bay (Beach, 1988).

Mammals, Reptiles and Amphibians

A walkover survey was conducted in 1987 by IEP, Inc. for the Army Corps of Engineers to assess wildlife use of the habitat of the Saugus and Pines Rivers Estuary. Wetland compartments were visited from June to September by foot and by boat. In addition, incidental observations of mammals, reptiles and amphibians were recorded during avian censusing and other field surveys by IEP personnel. A complete list of species observed or suspected of occurring in the Study Area wetlands is presented as Tables K46 (mammals) and K47 (herpetofauna).

Coastal wetland systems of the glaciated northeast provide excellent habitat for a wide variety of wildlife species. The Saugus and Pines Rivers Estuary is characterized by several distinct habitat types: tidal freshwater

Table K46. Mammals Observed in the Study Area Wetlands

Common Name	Scientific Name
Opossum	Didelphis marsupialis
Masked Shrew *	Sorex cinereus
Water Shrew *	Sorex palustris
Short-tailed Shrew *	Blarina brevicauda
Star-nosed Mole *	Condylura cristata
Little Brown Myotis	Myotis lucifugus
Keen's Myotis *	Myotis keeni
Silver-haired Bat *	Lasionycteris noctivagans
Eastern Pipistrelle *	Pipstrellus subflavus
Big Brown Bat *	Eptesius fuscus
Red Bat *	Lasiurus borealis
Hoary Bat *	Lasiurus cinereus
New England Cottontail	Sylvilagus transitionalis
Eastern Cottontail*	Sylvilagus floridanus
Woodchuck	Marmota monax
White footed Mouse	Peromyscus leucopus
Meadow Vole	Microtus pennsylvanicus
Muskrat	Ondatra zibethica
Norway Rat	Rattus norvegicus
House Mouse	Mus musculus
Meadow jumping Mouse *	Zapus hudsonius
Red Fox	Vulpes fulva
Raccoon	Procyon lotor
Long-tailed Weasel *	Mustela frenata
Mink	Mustela vison
Striped Skunk	Mephitis mephitis

* Not observed in study wetlands but can possibly occur within these wetlands based on known species ranges and habitat preferences.

Note: Observations by IEP, Inc. in 1987.

Table K47. Herpetofauna Observed in the Study Area Wetlands

Common Name	Scientific Name
Spotted Salamander *	Ambystoma maculatum
Red Spotted Newt *	Notophthalamus v. viridescens
Northern two-lined *	Desmognathus f. fuscus
Red Back Salamander *	Plethodon cinereus
Spring Peeper *	Hyla crucifer
American Toad	Bufo americanus
Gray Treefrog *	Hyla versicolor
Green Frog	Rana clamitans
Wood Frog	Rana sylvatica
Common Snapping Turtle	Chelydra serpentina
Spotted Turtle *	Clemmys guttata
Eastern Painted Turtle *	Chrysemys picta
Northern Water Snake *	Nerodia sipedon
Eastern Garter Snake	Thamnophis sirtalis
Eastern Ribbon Snake *	Thamnophis sauritus
Northern Black Racer *	Coluber constrictor

* Not observed in study wetlands, but can possibly occur within these wetlands based on known species ranges and habitat preferences.

Note: Observations by IEP, Inc. in 1987.

wetlands, high salt marsh, regularly flooded or low salt marsh and tidal flats. It is emphasized that the individual habitats do not function as isolated zones; ultimate wildlife value is determined by their interspersion and juxtaposition within the coastal wetland system. In the Saugus and Pines Rivers Estuary, there is relatively good interspersion of habitat types which, when coupled with the large size of the estuary (approximately 1660 acres) indicates a highly valuable and regionally important coastal wetland system.

Tidal freshwater wetlands are generally characterized as having near-freshwater conditions (below 0.5 ppt ocean-derived salts during the period of average annual low flow), a plant and animal community dominated by freshwater species and daily tidal fluctuations. A higher diversity of plants: broad-leaf plants, grasses, rushes, shrubs and herbaceous plants as well as animal species: reptiles, amphibians and furbearing mammals exist within this habitat as compared to the high salinity estuarine marshes (Odum et al., 1984). The upper Saugus River and Shute Brook (Compartments A and C) comprise a mixture of fresh and brackish waters with a high level of vegetative interspersion. These wetlands were frequented by the Muskrat (Ondatra zibethica), which utilizes the commonly occurring cattail (Typha spp.) as shelter and nesting cover and uses the starchy root stocks for food. In addition, species such as the Cottontail Rabbit (Sylvilagus sp.), Opossum (Didelphis marsupialis), Red Fox (Vulpes fulva) and Raccoon (Procyon lotor) were observed or evidenced by sign in this habitat. Use of the wetland by upland mammals such as the Raccoon, Red Fox and Opossum was more evident in the ecotone (wetland/upland transition) at the wetland perimeter where shrubby vegetation is used as food and cover. The riparian wetlands are also used as travel corridors. Several amphibians, such as the Red Back Salamander (Plethodon cinereus) and the Wood Frog (Rana sylvatica) were also observed utilizing this tidal freshwater habitat.

The high salt marsh, the area above Mean High Water (MHW), is formed through the accretion of sediments which become trapped in the intertidal zone vegetation. A high peat content in the substrate, infrequent tidal flooding and taxonomic differences distinguish the high salt marsh from the regularly flooded salt marsh (Nixon, 1982). The high salt marsh is dominated by salt meadow grass (Spartina patens) and spike grass (Distichlis spicata), with the high fringes often developing black grass (Juncus gerardii) and switch grass (Panicum virgatum). The regularly flooded salt marsh is characterized by the monospecific dominant saltmarsh cordgrass (Spartina alterniflora). Mammals comprise a smaller and generally less conspicuous part of the high marsh fauna than birds. The Meadow Vole (Microtus pennsylvanicus) is probably the most abundant species, most often inhabiting the high marsh dense grass mat of S. patens and D. spicata. Several other mammals, such as the White-footed Mouse (Peromyscus leucopus), Meadow Jumping Mouse (Zapus hudsonius) and Masked Shrew (Sorex cinereus) are also present. The Norway Rat (Rattus norvegicus) and House Mouse (Mus musculus) were evidenced in many of the small isolated wetlands (Compartments G, H and J) characterized by Phragmites encroachment, testimony to their adaptability to altered and disturbed habitats. The small burrows and runs encountered during investigations and the presence of the rodent-hunting Northern Harrier (Circus cyaneus) suggest that rodent populations may be high in several areas. Larger mammals such as the Raccoon

and the Skunk (Mephitis mephitis) feed on birds eggs and mice in the marsh while their homes are generally in upland trees (Raccoon) and dens (Skunks) (Nixon, 1982).

The regularly flooded salt marsh functions as a sediment trap for sand and silt particles carried by the ebb and flood of the tides. It is characterized by a wet, muddy substrate and a flat topography dominated by the monospecific Spartina alterniflora, a plant capable of survival in salt water. Numerous tidal creeks, small ponds and pannes occur throughout the low marsh (Teal, 1986). While obvious use of this habitat by herpetofauna was not observed during this study, some species as listed in Table K47 may occur. Larger mammals such as Raccoons, Mink (Mustela vison), Weasels (Mustela frenata) and occasionally Red Foxes also feed on shellfish within the intertidal zone.

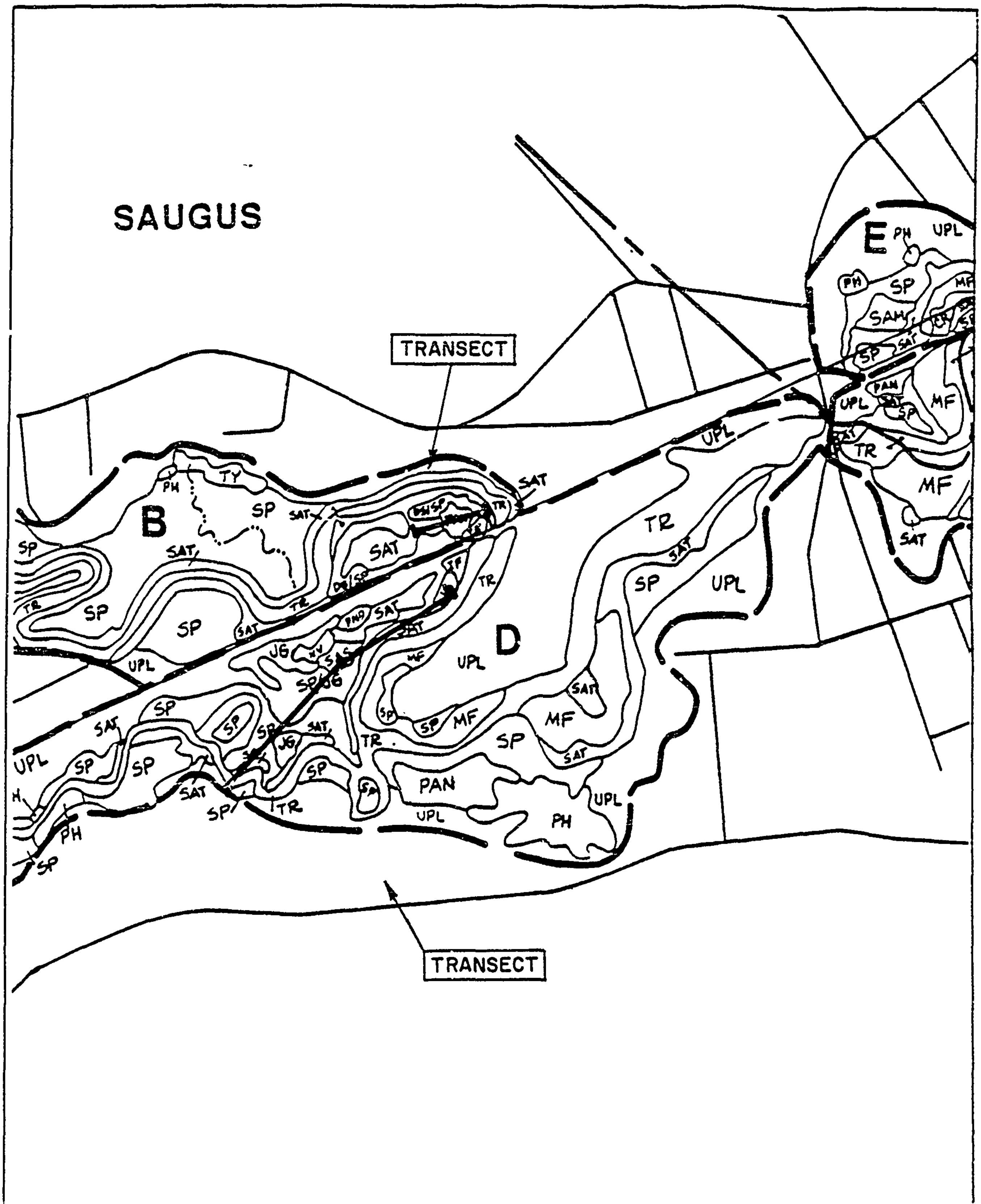
Some of the same species discussed above (Muskrat, Raccoon, Red Fox and Cottontail Rabbit) are described in abundance in the Study Area woodlands in historical accounts of Lynn (Lewis and Newhall, 1865). The Red Fox and Cottontail Rabbit undoubtedly utilized the wetlands, but to a lesser extent than now, considering the availability of upland habitat at that time. Development of the surrounding upland and alterations to the wetland environment more readily affected populations of larger mammals such as the Whitetail Deer (Odocoileus virginianus), Moose (Alces alces) and Black Bear (Ursus americanus), which no longer exist in the Study Area.

Birds

Bird Surveys in the Study Area

Surveys, including fixed width belt transects, circular plot surveys and bird platform surveys conducted in 1987 by IEP,Inc. for the Army Corps of Engineers yielded an abundance of information on the occurrence of birds in the Saugus and Pines Rivers Estuary. The fixed width belt transect method involves an observer traversing a transect of known length and width and recording avian species sighted or flushed. This method enables a quick census of large areas for avian density and richness. Variable circular plots were used in areas difficult to traverse or where vegetation densities limited viewing capabilities. A stationary observer recorded all avian species identified by sight or song from within a circular plot center for a specified period of time. This methodology may be used to determine the composition of avian species in a particular area or habitat. Species which were readily identified and counted from a distant point with a spotting scope and/or binoculars were tallied by platform counts. This method is used to census large birds over large areas such as ducks, wading birds and those which feed or hunt on-the-wing. As well, supplemental avifaunal use data was collected during incidental field visits.

Fixed width belt transects were conducted following methods described by Franzeb (1981) on wetland Compartments B/D, K1, K3 and M to quantify the abundance of breeding birds in these wetlands. The location of transects used are shown in Figures K28, K29 and K30. Each transect was censused six times to determine bird density and diversity along the 500 meter

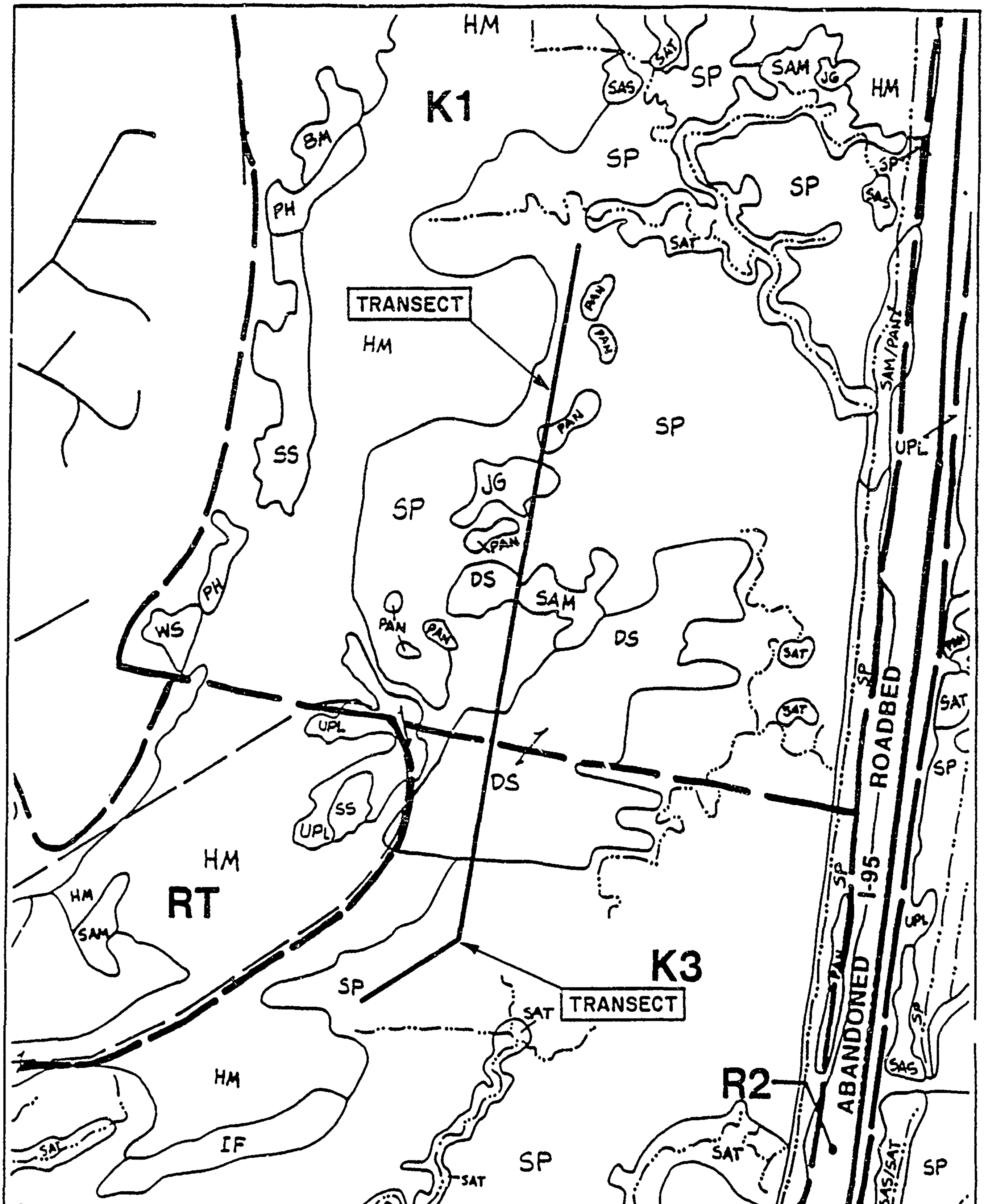


SCALE:
1" = 500'

SAUGUS / PINES RIVERS
ESTUARINE WETLANDS STUDY

COMPARTMENT B / D
FIXED-WIDTH AVIAN
TRANSECT LOCATION

Figure K28

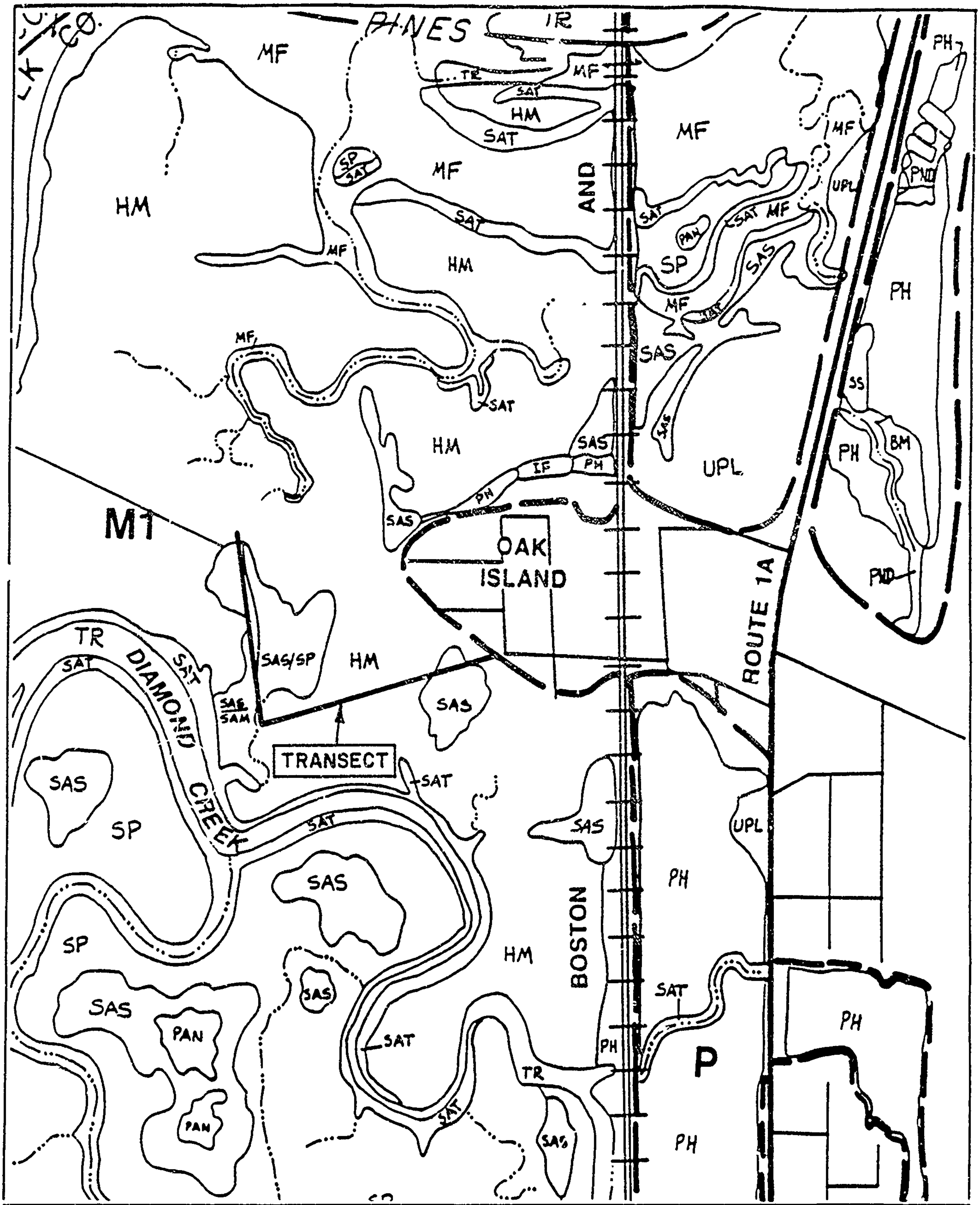


SCALE: 1" = 500'

SAUGUS / PINES RIVERS ESTUARINE WETLANDS STUDY

COMPARTMENTS K_1 & K_3
FIXED-WIDTH AVIAN TRANSECT LOCATIONS

Figure K29



SCALE:
1" = 500'

SAUGUS / PINES RIVERS
ESTUARINE WETLANDS STUDY

COMPARTMENT M
FIXED-WIDTH AVIAN
TRANSECT LOCATION

Figure K30

length of the transect and 30 meter width on each side of the center line. Transects began approximately 1/2 hour before dawn, as long as fog and daylight permitted the visual observation of birds. The observer walked at a steady rate of 1 kilometer/hour.

A circular plot was established in wetland Compartment A on the Saugus River and in Compartment C on Shute Brook to calculate the density of breeding birds in robust, persistent emergent vegetation. The location of circular plots are shown in Figure K31. The methodology used was that of Reynolds, et al. (1981). Each area was censused on two occasions beginning approximately 1/2 hour before dawn as long as there was sufficient light to see birds. There was no fixed radius plot, but rather each bird was first identified and the distance from the observer was calculated to the nearest meter. Each census lasted for 1/2 hour which seemed to be sufficient time to identify the majority of bird species present.

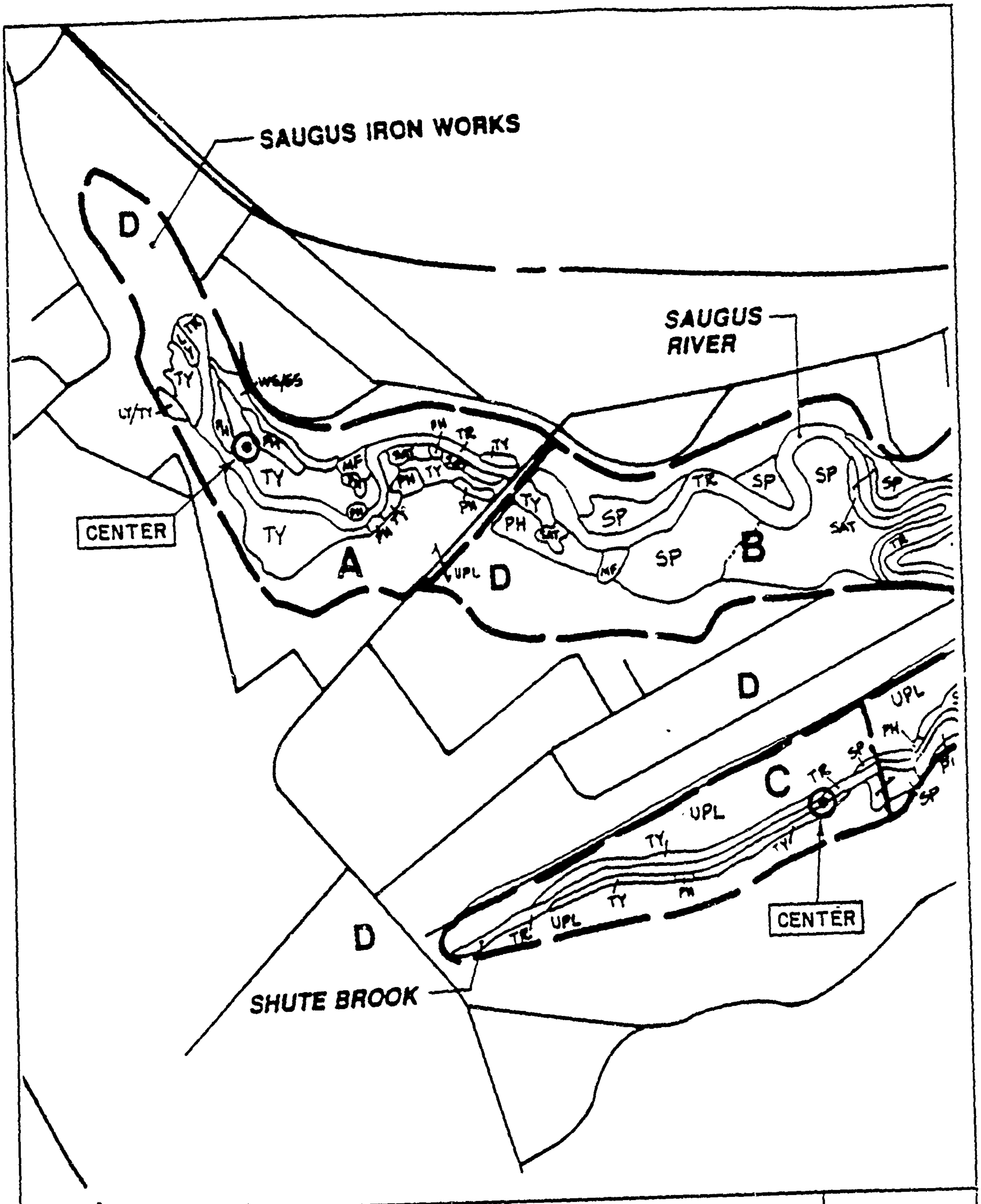
Eight bird platforms, or elevated lookout points, were established throughout the Study Area to observe large birds that might not be recorded using other methods. The techniques used were those of Reinert et al. (1981). Sites were chosen and boundaries were established for the area of coverage so that there was no overlap. A spotting scope was used to slowly scan the area. Hand held binoculars were often used to identify specific birds. Each platform was visited on two occasions. Censuses were not conducted if there were high winds which would influence bird movements, except for the second census at the General Edwards Bridge (this atypical data was not included in the analysis which is in keeping with suggestions by Reinert et al. (1981) who did not census during windy periods). The eight census locations are designated on Figure K32.

Bird Habitats

Each of the many habitat types in the estuary have particular attributes which provide the necessary conditions to support the various life processes of different avian species.

Of the types of coastal wetlands, tidal freshwater wetlands are the most structurally diverse. The edge effect created through the juxtaposition of low marsh, tidal channels, open water areas, shrubs and trees of the high marsh and upland supports a wide variety of habitat requirements and therefore a greater diversity of avian life. For example, herons and shorebirds forage on the exposed mud flats and tidal channels, the shrubs and trees along the marsh-upland ecotone provide nesting sites for many arboreal birds which can be found feeding over the marsh proper, and waterfowl use the marsh surface for nesting as well as the open water for foraging (Odum et al., 1984). In addition, the tidal freshwater wetland provides fresh water to those species incapable of extracting salt through biological mechanisms.

Tidal flats in the estuary as well as along the coastal shorefronts in Lynn and Revere may be exploited by a large number of species. For some, such as herons and shorebirds, tidal flats are absolutely essential habitat, while for others, such as diving ducks, tidal flats at high tide are another potential foraging site (Whitlatch, 1982). Shorebirds feed primarily

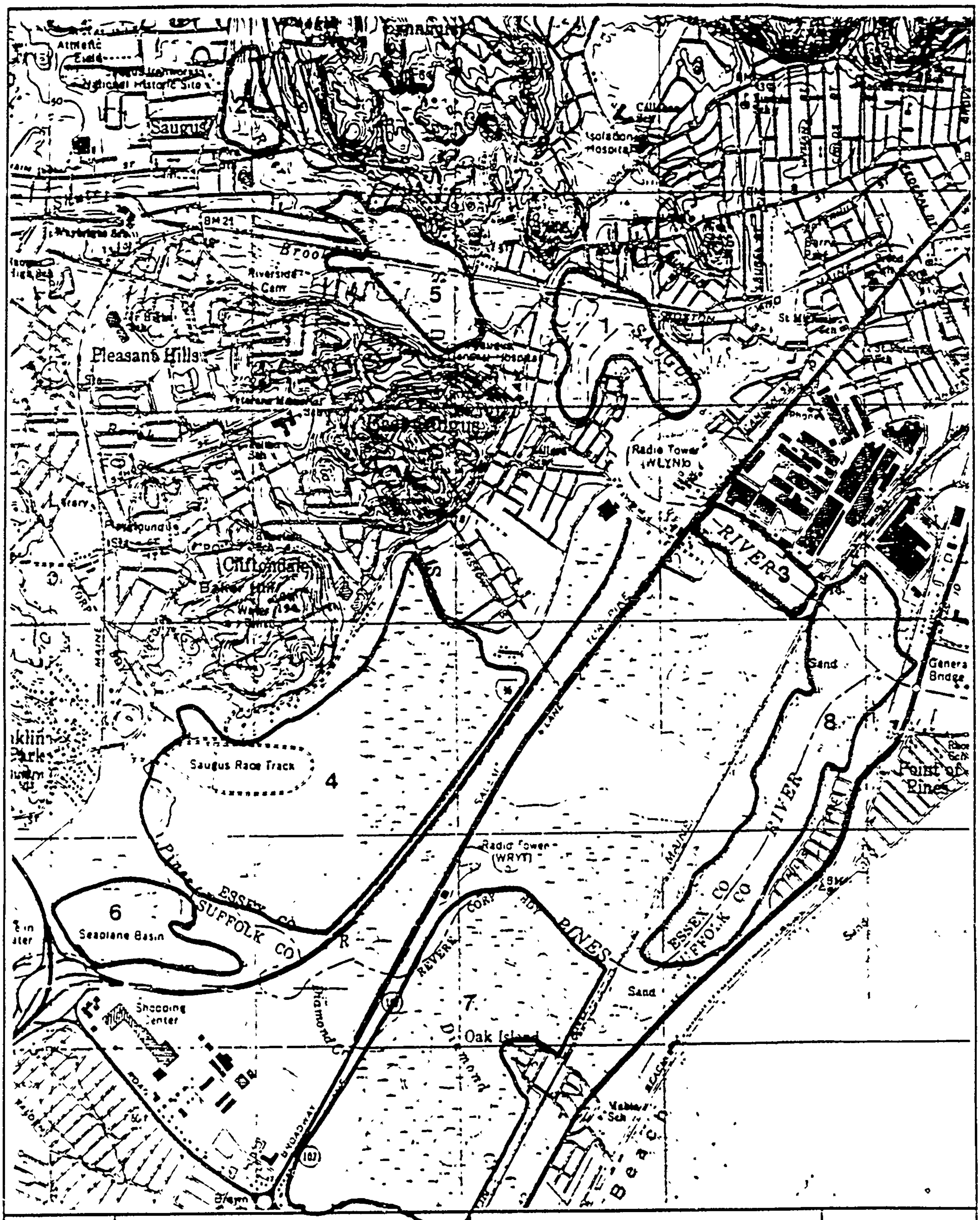


SCALE: 1" = 500'

SAUGUS / PINES RIVERS
ESTUARINE WETLANDS STUDY

COMPARTMENTS A & C
AVIAN CIRCULAR
PLOT CENTERS

Figure K31



SCALE:
1" = 2083'

SAUGUS / PINES RIVERS ESTUARINE WETLANDS STUDY

STRATEGIC OBSERVATION LOCATIONS FOR AVIAN CENSUSING

Figure K32

on invertebrates (mollusks, crustaceans, polychaetes) that are captured on sand beaches and mud flats; different shorebird species may prefer different substrate types. The greater the variety of tidal flat substrate types, the greater the potential diversity of shorebird species. Gulls and terns are most often attracted to shallow water zones to feed on schools of small fish, with the gulls also commonly found foraging in exposed flats or rocky intertidal shores for shellfish.

In the typical New England saltmarsh, there are only a handful of bird species which nest in the regularly flooded S. alterniflora marsh. They include Clapper Rails (Rallus longirostris), Black Ducks (Anas rubripes), Marsh Wrens (Cistothorus palustris), Red-winged Blackbirds (Agelaius phoeniceus), Sharptailed Sparrows (Ammospiza caudacuta) and Seaside Sparrows (Ammospiza maritima). Considerably more species feed within the regularly flooded marsh or use the habitat seasonally for resting or cover. Wading birds often stalk the fish and crustacea along the creeks within the marsh (Teal, 1986). The high salt marsh is a more common nesting site for Sharptailed and Seaside Sparrows, and may also serve as nesting habitat for Marsh Hawks (Circus cyaneus), Short-eared Owls (Asio flammeus), Black Ducks, Canada Geese (Branta canadensis), gulls, terns and Red-winged Blackbirds. A number of upland or freshwater wetland bird species use the high marsh as feeding areas, while swallows and chimney swifts (Chaetura pelagica) commonly feed on insects over the marsh (Nixon, 1982).

Breeding Season - Nesting, Resting and Foraging Species

Among the species reported by local citizens to breed in the estuary and its surroundings are the Eastern Meadowlark (Sturnella magna), Spotted Sandpiper (Actitis macularia), Sharp-tailed Sparrow, American Kestrel (Falco sparverius), Common Tern (Sterna hirundo), Killdeer (Charadrius vociferus), Red-tailed Hawk (Buteo jamaicensis), Black Duck and Mallard. Suspected breeders include Marsh Wren, Savannah Sparrow (Passerculus sandwichensis) and Blue-winged Teal (Anas discors) (ACEC Nominating Committee, 1988). Additional information on nesting, resting and foraging birds from the 1987 survey conducted by IEP, Inc. during June - September is discussed in the following paragraphs. Table K48 presents bird occurrence, by wetland compartment; Table K49 provides bird densities from the fixed-width transects; Table K50 presents results of the circular plot surveys; and Table K51 presents results of the bird platform surveys.

The diversity of wetland types: open riverine water, intertidal flats, tidal fresh/brackish marsh and bordering wood swamp and forest make the Upper Saugus River and Shute Brook (Compartments A and C) attractive to a wide variety of birds which are lacking in the lower estuary. One of the most commonly found are nesting Red-winged Blackbirds. Herons and egrets frequently feed along the rivers' edges and Black-crowned Night Herons (Nycticorax nycticorax) use the area for roosting. Aerial feeding birds such as swifts and swallows are very common due to nearby nesting sites provided by buildings at the Saugus Iron Works. Starlings (Sturnus vulgaris) make use of Compartments A and C as brood-rearing, feeding and resting habitat. Black Ducks and Mallards were observed in the upper Saugus River and Shute Brook (Compartments A, B, C, D), with their broods, foraging along the rivers'

Table K48. Saugus River and Tributaries Bird List

Species	Wetland A	B	C	D	E	F	G	H	I	J	K1	K2	K3	L1	L2	M1	M2	N1	N2	N3	O	P
Double-crested Cormorant		x		x	x	x			x		x	x	x	x	x	x	x		x			
Great Blue Heron	x								x		x					x		x				
Green-backed Heron	x	x									x											
Black-crowned Night Heron	x								x		x		x			x	x					
Glossy Ibis*																						
Great Egret		x									x		x			x						
Snowy Egret				x		x			x		x	x	x	x	x	x	x					
Little Blue Heron																						
Common Goldeneye*																						
Common Merganser*																						
American Black Duck	x	x		x		x			x				x			x						
Mallard	x	x	x	x							x		x									
Wood Duck*																						
Canada Goose											x											
Clapper Rail*																						
Broad-winged Hawk*																						
Red-shouldered Hawk*																						

Table K48 (continued)

Species	A	B	C	D	E	F	G	H	I	J	K1	K2	K3	L1	L2	M1	M2	N1	N2	N3	O	P
Northern Harrier																x						
American Kestrel																						
Great Horned Owl*																						
Short-eared Owl*																						
Snowy Owl*																						
Ring-necked Pheasant		x									x		x									
Black bellied Plover									x			x				x						
Killdeer		x				x						x										
Semi-palmated Plover		x		x		x						x				x						
Common Snipe																x						
Shorebird sp.											x		x			x						
Solitary Sandpiper		x		x							x					x						
Whimbrel											x											
Spotted Sandpiper										x			x	x								
Semi-palmated Sandpiper		x		x		x						x				x				x		
Lesser Yellowlegs		x		x		x				x		x				x				x		
Greater Yellowlegs				x		x					x	x	x			x				x		
Shorter-billed Dowitcher		x		x								x										
Greater Black-backed Gull						x			x			x			x	x		x	x	x		
Herring Gull	x	x	x		x	x			x		x	x	x	x	x	x			x			
Ring-billed Gull	x			x		x			x			x						x	x			
Common Tern									x						x	x			x			
Rock Dove	x	x				x				x	x		x						x			
Ruffed Grouse																						

Table K48 (continued)

Species	A	B	C	D	E	F	G	H	I	J	K1	K2	K3	L1	L2	M1	M2	N1	N2	N3	O	P
Mourning Dove		x								x												
Chimney Swift	x	x				x					x		x			x						
Common Nighthawk*																						
Belted Kingfisher		x											x			x						
Common Flicker		x	x								x		x									
Barn Swallow	x	x	x			x					x		x			x						
Tree Swallow		x														x						
Rough-winged Swallow*																						
Cliff Swallow	x										x		x			x						
Great Crested Flycatcher*																						
Eastern Phoebe*																						
Eastern Wood Pewee*																						
Eastern Kingbird	x	x	x								x		x									
Black-billed Cuckoo*																						
Blue Jay	x	x																				
Downy Woodpecker	x																					
Hairy Woodpecker	x																					
Red-headed Woodpecker*																						
Common Crow	x	x		x	x								x						x			
Northern Oriole*																						
Tufted Titmouse*																						
Black-capped Chickadee		x																				
Brown Creeper*																						

Table K48 (continued)

Species	A	B	C	D	E	F	G	H	I	J	K1	K2	K3	L1	L2	M1	M2	N1	N2	N3	O	P
Northern Mockingbird	x	x	x								x		x									
Gray Catbird		x	x								x											
Brown Thrasher*																						
Veery*																						
Wood Thrush*																						
Hermit Thrush*																						
Red-breasted nuthatch*																						
American Robin	x	x	x										x									
Cedar Waxwing		x																				
European Starling	x	x	x			x			x		x		x			x	x				x	x
House Wren*																						
Ovenbird*																						
Red-eyed Vireo*																						
Warbling Vireo*																						
Prairie Warbler*																						
Yellow Warbler	x	x	x										x									
Common Yellowthroat	x	x	x								x		x									
Black and White Warbler*																						

Table K48 (continued)

Species	A	B	C	D	E	F	G	H	I	J	K1	K2	K3	L1	L2	M1	M2	N1	N2	N3	O	P
Red-Winged Blackbird	x	x	x			x			x		x		x			x						
Brown-headed Cowbird		x																				
Meadowlark*																						
Common Grackle	x	x									x		x			x				x		
House Finch	x		x																			
Purple Finch			x																			
Indigo Bunting																						
Rose-breasted Grosbeak																						
Cardinal*																						
Song Sparrow	x	x	x								x		x			x						
Swamp Sparrow	x	x																				
Chipping Sparrow*																						
Sharp-tailed Sparrow		x							x		x		x			x						
Seaside Sparrow		x																				
American Goldfinch			x								x											
House Sparrow	x																					
Field Sparrow*																						
	A	B	C	D	E	F	G	H	I	J	K1	K2	K3	L1	L2	M1	M2	N1	N2	N3	O	P
Total Species	27	38	16	12	3	16	0	0	13	4	29	12	28	4	5	28	4	3	7	5	1	1

* Species which previous investigations have recorded in study wetlands, but which were not recorded during 1987 census investigations.

Table K49. Bird Densities (birds/40 ha) Recorded Using Fixed-width Transects at Wetlands B/D, K1, K3, M1.

	Wetland			
Species	B/D	K1	K3	M1
Double-crested Cormorant	53.3	13.3	13.3	106.7
Green-backed Heron	13.3	13.3	-	-
Black-crowned Night Heron	-	13.3	40.0	26.7
Great Egret	13.3	-	-	53.3
Snowy Egret	-	-	-	40.0
American Black Duck	-	-	-	40.0
Mallard	733.3	-	26.7	-
Ring-necked Pheasant	26.7	-	-	-
Killdeer	40.0	-	-	-
Semi-palmated Plover	13.3	-	-	-
Common Snipe	-	-	-	13.3
Shorebird sp.	-	-	26.7	120.0
Solitary Sandpiper	26.7	13.3	-	40.0
Spotted Sandpiper	-	-	13.3	-
Semi-palmated Sandpiper	-	-	-	-
Lesser Yellowlegs	80.0	-	26.7	-
Greater Yellowlegs	-	80.0	120.0	40.0
Short-billed Dowitcher	266.7	-	-	-
Herring Gull	213.3	-	40.0	173.3
Common Tern	-	-	-	53.3
Rock Dove	26.7	-	-	-
Mourning Dove	13.3	-	26.7	-
Chimney Swift	13.3	13.3	-	200.0
Common Flicker	-	13.3	-	-
Barn Swallow	-	13.3	-	-
Tree Swallow	26.7	-	-	26.7
Cliff Swallow	-	53.3	13.3	26.7
Eastern Kingbird	-	13.3	13.3	-
Common Crow	80.0	-	-	-
Northern Mockingbird	13.3	-	13.3	-
Gray Catbird	13.3	-	-	-
American Robin	40.0	-	-	-
European Starling	1280.0	1306.0	1453.3	300.0
Yellow Warbler	13.3	-	-	-
Common Yellowthroat	13.3	13.3	-	-
Red-winged Blackbird	440.0	546.7	360.0	466.7
Brown-headed Cowbird	26.7	-	-	-
Common Grackle	173.3	40.0	120.0	146.7
Song Sparrow	186.7	26.7	13.3	-
Swamp Sparrow	53.3	-	-	-

Table K49. Bird Densities (birds/40 ha)
(Continued)

	Wetland			
Species	B/D	K1	K3	M1
Sharp-tailed Sparrow	53.3	266.7	533.3	53.3
Seaside Sparrow	26.7		-	-
American Goldfinch	280.0	13.3	146.7	200.0
Total Density (per 40 ha)	4253.1	2452.4	2999.9	2126.7

Table K50. Bird Densities (birds/40 ha) Recorded at Wetland Sites A and C[1].

Species	Wetland A	Wetland C
Mallard	207.9	52.0
Herring Gull	203.7	6.4
Common Flicker	--	141.5
Barn Swallow	3678.4	212.2
Cliff Swallow	203.7	--
Swallow sp.	--	141.5
Eastern Kingbird	--	159.2
Common Crow	353.8	--
Gray Catbird	--	101.8
American Robin	--	159.2
European Starling	102.2	141.5
Yellow Warbler	318.3	--
Common Yellowthroat	565.9	159.2
Red-Winged Blackbird	495.2	1414.8
Common Grackle	694.5	--
Song Sparrow	199.0	477.4
Swamp Sparrow	212.2	--
Total	7234.8	3166.7

[1]Data recorded using Variable Circular-plot Method.

Table K51. Platform Census Data for the Saugus River and Tributaries: Total Number of each Species Observed and Total Density by Wetland.*

	Platform Number							
Species	1	2	3	4	5	6	7	8
Double-crested Cormorant	4		4			21	7	11
Great Blue Heron		1		2			3	
Snowy Egret	1		3	13		11	6	
American Black Duck	2							
Mallard		4			10			
Northern Harrier							1	
Black-bellied Plover						40	3	
Killdeer	1					1		
Semipalmated Plover						72	300	
Shorebird sp.				1				
Upland Sandpiper				2				
Semipalmated Sandpiper	8					68	77	
Lesser Yellowlegs						1	1	
Greater Yellowlegs	1			7		6	20	
Short-billed Dowitcher						12		
Greater Black-backed Gull	7		15			3	2	7
Herring Gull	14		54		2	13	8	17
Ring-billed Gull	4	1				2		3
Gull sp.					1			
Rock Dove		4		2			2	
Belted Kingfisher					1		1	
Eastern Kingbird		1						
Barn Swallow		6						
Common Crow		2			2			2
Northern Mockingbird					1			
European Starling	26	28			2		80	
House Sparrow		9						
Total	68	56	76	27	19	250	511	40
Density (birds/40 ha)	50	133.3	115.2	3.7	14.0	189.4	84.0	12.5
Acreage	68	21	33	362	68	66	304	160

* Based on 2 census days for each wetland except wetland 8, in which one census was conducted.

edges. Although no nests were found, it is likely that nesting occurs in the upper reaches of these rivers, within or adjacent to the wetland, where fresh water is accessible.

The lower Saugus River from the Lincoln Avenue Bridge to the General Edwards Bridge is dominated by areas of open water and tidal flats with limited areas of vegetated salt marsh (Compartments D, F, I and N2). Primary inhabitants of these environments as well as the coastal shorefronts of Lynn and Revere are gulls, terns and cormorants which use the area for feeding. Herons and egrets use the tidal flats, tidal creeks and ditches for feeding on invertebrates. These birds nest on isolated islands off site, while utilizing the estuary for feeding to help satisfy the high energetic demands of raising nestlings.

Concerning Snowy Egrets (Egretta thula), a population census in 1984 found 888 pairs of Snowy Egrets breeding in 14 colonies in Massachusetts (Kent, 1987). The closest colonies to the Study Area were Kettle Island, 22 km north and three colonies in Boston Harbor. Kent observed all Snowy Egrets leaving the marsh from the 160 acre portion of the estuary behind a barrier spit at the mouth of the Saugus River (Compartment I) over a five day period. Of the 120 birds leaving, 75 were observed landing in other parts of the marsh and were excluded from analysis. The remaining 45 individuals engaged in long flights characteristically flew higher and occasionally spiraled on thermals above the marsh. The direction of flight at last visual contact was recorded. Analysis of flight patterns determined that Snowy Egrets consistently flew southward when leaving the marsh. This research suggests that the Snowy Egrets foraging in the Saugus and Pines Rivers Estuary are nesting in Boston Harbor.

The large expanses of salt marsh (Compartments M1, M2, K1, K3 and RT) provide suitable nesting areas for the Sharp-tailed Sparrow and other ground nesting birds. Herons and egrets could often be seen foraging in the salt marsh. Black-crowned Night Herons were often observed roosting in the shrubs and trees developing along the I-95 embankment. As well, the eastern portions of the Saugus Race Track (on filled portions of the salt marsh) contain forested upland islands and shrub and tree species invading the salt marsh. As a result, many birds typically found in upland areas, including the Ring-necked Pheasant (Phasianus colchicus), swallows, swifts, Blue Jays (Cyanocitta cristata) and others were observed there. Few birds were observed utilizing the wetland areas characterized by Phragmites encroachment (Compartments G, H and J).

Migratory Species

During shorebird migration, particularly during August and September 1987, large groups of shorebirds were observed feeding on the tidal and algal flats and along rocky shorelines in the Study Area. The dominant shorebirds were the Semipalmated Sandpiper (Calidris pusilla), Semipalmated Plover (Charadrius semipalmatus), Short-billed Dowitcher (Limnodromus griseus) and Lesser Yellowlegs (Tringa flavipes), although other shorebirds were observed. Black Ducks and Mallards were also present. Highest use in the estuary during migration was observed in the areas where the salt water begins to be heavily

diluted by fresh water and the diversity of plant species increases (Compartments B and D), areas of high interspersion of open water and tidal flats (Compartments M1 and N2) and the Sea Plane Basin (K2)(IEP, Inc., 1988). Compartment D (Upper Saugus River) was one of the most extensively used areas by Black Ducks during migration. During the fall migratory period (August to October), relatively large numbers (50-100) of Black Ducks and Mallards were observed foraging along the river's edge in Compartment D. During high tide, these ducks used the adjacent salt marsh as preening and resting areas. The occurrence of duck hunting blinds in various locations throughout the salt marsh adjacent to the lower Pines River (Compartment M1) suggests that there is frequent use of that area by ducks also. Local birders report observing Peregrine Falcons (Falco peregrinus) and Ospreys (Pandion haliaetus) over the marsh during fall migration (USFWS, 1987). These and other raptors undoubtedly occur in both fall and spring. Various species of passerines and other landbirds also migrate through the Study Area in both fall and spring.

Wintering Species

Significant changes occur in the salt marsh during the winter months. Animal life adjusts to the harsh environment through physiological or behavioral adaptations. Many are resting, hibernating or have migrated south to warmer climates. The more northern the marsh, the less difference the tides make to animals in the winter as ice and snow limits foraging. Feeding activity is generally limited to the open water where ducks and gulls can chase small fish that have been slowed by the cold, or they poke in the mud to sift small worms and clams. Hunting in the marsh is difficult as the mud becomes frozen and worms and insect larvae have retreated deep into the mud (Teal and Teal, 1977).

Marsh vegetation is also affected by cold winter temperatures. Only the roots survive freezing under a layer of matted vegetation. Seeds are utilized as a winter food source as supplies are available. Some species found in the estuary in winter include the Starling, Crow (Corvus brachyrhynchos) and Ring-necked Pheasant (in the fresh/salt water transition and shrubby areas); Sanderlings (Calidris alba) may be seen foraging along sandy beaches and mud flats and the Herring Gull (Larus argentatus) and Great Black-backed Gull (Larus marinus) are seen foraging or resting in open water habitats. A winter waterfowl census conducted on December 18, 1987 by a Corps of Engineers biologist showed use of the Saugus and Pines Rivers and Lynn Harbor by Buffleheads (Bucephala albeola), Red-breasted Mergansers (Mergus serrator), Canada Geese, Mallards, Black Ducks, Common Eiders (Somateria mollissima), Brant (Branta bernicla) and Common Goldeneyes (Bucephala clangula). Numerous other species are also found regularly, especially in Lynn Harbor, in winter. Dabbling ducks, such as the Mallard and Black Duck, utilize mud flats during low tide while the diving ducks such as the Bufflehead and the Red-breasted Merganser forage these areas at high tide. Raptors of several species may utilize the marsh in winter and various species of passerines and other landbirds can be found in winter, primarily along the fringes of the marsh. The Snowy Owl (Nyctea scandiaca) may be an infrequent winter visitor to the Study Area (USFWS, 1987).

The Saugus and Pines Rivers Estuary provides valuable wintering habitat for the Black Duck. A sharp decline in the Black Duck population, nationally, between 1955 and 1962 and a gradual decrease since the 1960's by 1.5 percent a year have caused concern and facilitated implementation of some protection measures (CCP, undated). Hunting mortality, destruction of wetland habitat necessary for feeding and nesting by development and pollution, and the effects of competition and interbreeding with its close relative the Mallard, have undoubtedly contributed to the decline.

Characteristically, Black Ducks strongly attach to specific wintering places, many returning to the same marshes they visited the previous year. Some always winter on the New England coast, moving southward only if the weather is severely cold. Attachment to specific areas is so strong that, in some cases, if the marshes freeze, some Black Ducks have starved to death rather than move southward (Bellrose, 1980).

Personnel from the Massachusetts Division of Fisheries and Wildlife (MDFW) have conducted winter banding surveys in the upper Lynn Harbor area (at the head of the causeway to Nahant) since 1966. Formerly, Black Ducks numbered approximately 600 individuals. Most recent inventories estimate the Black Duck population to be reduced to a few dozen in the Lynn survey area (H. W. Heusmann, Waterfowl Biologist, MDFW, 1988 - Personal Communication).

Informal censusing through visual observation by MDFW personnel in the Saugus and Pines Rivers Estuary in recent years estimates from 120 to 180 Black Ducks wintering in the estuary, a slight increase in numbers over the years immediately prior. It is speculated that a reduction in regional wetland habitat, suitable wintering habitat, or perhaps the effects of pollution on food resources in Boston Harbor, have led to the increased utilization of this estuarine/river habitat (H. W. Heusmann, Waterfowl Biologist, MDFW, 1988 - Personal Communication).

Black Ducks feed on eelgrass, widgeon grass, periwinkles, blue mussels and various snails in water approximately 12 to 18 inches in depth. They are adapted to feeding at different tide regimes, moving out toward the bay as the tide ebbs and moving in toward the marsh as the tide floods. They utilize the entire Saugus and Pines Rivers Estuary; however, there are three preferred feeding sites: the mussel flats located on both sides of the Saugus River under and around the General Edwards Bridge, and the mussel flats located on the Saugus River directly behind the General Electric plant. The area under and around the bridge is particularly important during the winter months because this section of river seldom freezes. Black Ducks also feed in the high marsh at the higher high tides (for a few to several days each month) on seeds and snails which hibernate in the marsh grass (H. W. Heusmann, Waterfowl Biologist, MDFW, 1988 - Personal Communication).

Historical Conditions

From a historical perspective, it was written of the Study Area that "The wild fowl were so numerous in the waters, that persons sometimes killed 50 ducks at a shot". This historical account from Lewis and Newhall (1865), however exaggerated, suggests a sizeable duck population. Urban

encroachment and the destruction of wetlands in Massachusetts, as well as in northern breeding areas, have undoubtedly led to a decline in duck populations in the Study Area. Historical use of the Study Area wetlands by birds other than waterfowl is unknown. It may be speculated that similar species utilized the area in the past; however, there may have been a greater diversity of avian species and larger populations of the same.

Terrestrial Ecosystem

Upland Habitats

Existing Conditions

The terrestrial environment surrounding the Saugus and Pines Rivers is composed of urban and suburban development. Two small parcels remain the only relatively undisturbed upland forest habitat in the vicinity of the Study Area. One site is located north of the upper Saugus River (approximately 90 acres) and the other is northwest of the Sea Plane Basin on the Pines River (approximately 50 acres).

Only remnants of the endemic forest communities remain, interspersed with ornamental plantings, lawn, buildings, industrial development, roads and parking lots throughout most of the area. Fringes of shrub and forested swamp and upland forest border the marsh in the upper estuary and along Baker Hill. The following tree and shrub species were identified along these fringes during field investigations: White Ash (*Fraxinus americana*), American Elm (*Ulmus americana*), Red Maple (*Acer rubrum*), Speckled Alder (*Alnus rugosa*), Red Oak (*Quercus rubra*), White Pine (*Pinus strobus*), White Brich (*Betula papyrifera*) and Red-osier Dogwood (*Cornus stolonifera*).

Historical Conditions

The boundary between the transitional Northern Hardwood (Beech, Birch, Maple) and Oak Forest communities transects the project area (Bailey, 1976). Prior to urban/suburban development, the Study Area was blanketed with a mixture of the two communities; Northern Hardwoods developed in mesic conditions; the Oak Forest community, being more tolerant to droughty soils, developed on the somewhat excessively to excessively drained soils.

Organisms

Mammals, Reptiles and Amphibians

Existing Conditions

The Study Area uplands support typical urban wildlife such as the Red Fox (*Vulpes fulva*), Opossum (*Didelphis marsupialis*), Gray Squirrel (*Sciurus carolinensis*), Raccoon (*Procyon lotor*), Skunk (*Mephitis mephitis*), House Mouse (*Mus musculus*), Norway Rat (*Rattus norvegicus*) and Garter Snake (*Thamnophis sirtalis*).

The term 'terrestrial wildlife' is somewhat of a misnomer considering that many terrestrial species are often found in association with water or wetlands some time during their life history. Wetland habitat can provide food, escape cover, breeding or nesting habitat to terrestrial species. When upland habitat is destroyed, this use of wetland habitat may become more pronounced and/or prolonged. Some upland species may be forced to adapt to the wetland environment when the upland environment is developed for human use (AWRA, 1978). For example, animals typically found in upland areas, such as the Red Fox and Opossum, were observed along the wetland border during fieldwork for this study. The wetland provides a refuge from the surrounding urban landscape and berry producing shrubs bordering the wetland are a food source attractive to many wildlife species.

Historical Conditions

The consequence of urban/suburban development in the Study Area has been a significant reduction in the number and diversity of upland species in the Study Area. Species such as the Black Bear (Ursus americanus) and Whitetail Deer (Odocoileus virginianus), which formerly ranged in the Study Area (Lewis and Newhall, 1865), were unable to satisfy habitat requirements and/or tolerate human interaction and therefore no longer exist in the Study Area. Many woodland species were unable to tolerate, adapt or escape the destruction of habitat and have been supplanted by those species typical of the urban/suburban landscape.

Birds

Existing Conditions

The terrestrial habitat surrounding the Saugus and Pines Rivers Estuary is urban/suburban. Generally, the bird species capable of adapting to the urban landscape have a wide ranging tolerance of habitat type and foodstuff, smaller habitat size requirements and are tolerant of human interaction. Many species benefit from the use of structures such as bridges and buildings as nesting sites as these areas are inaccessible to terrestrial predators. As well, winter bird feeders provide a supplemental source of food. Winter and/or summer resident species typical of this type of setting are the House Finch, White-breasted Nuthatch, Blue Jay, Robin, Chimney Swift, Common Grackle, Starling, Rock Dove and English Sparrow.

In areas where trees and shrubs offer adequate food and cover, additional species might be observed in winter and summer in the terrestrial habitat surrounding the Saugus and Pines Rivers Estuary. The fruits and seeds of woody plants such as Oaks (Quercus spp.), Birches (Betula spp.), Maples (Acer spp.), Pines (Pinus spp.) and Alders (Alnus spp.) are utilized by the Black-capped Chickadee (Parus atricapillus), Purple Finch (Carpodacus purpureus), Cardinal (Cardinalis cardinalis) and Slate-colored Junco (Junco hyemalis), while the tree boles harbor insects for foraging Hairy (Picoides villosus) and Downy Woodpeckers (Picoides pubescens). Oak leaves and twigs are used by many birds as nesting material (Martin et al., 1951).

Use of wetland vegetation as food, cover, breeding or nesting habitat may become more pronounced by terrestrial birds with the destruction of upland habitat. Some upland species may be forced to adapt to the wetland environment when the upland environment is developed for human use (AWRA, 1978). For example, birds such as the Ring-necked Pheasant (*Phasianus colchicus*), Swallows (*Hirundinidae*), Chimney Swifts (*Chaetura pelagica*), Blue Jays (*Cyanocitta cristata*) and others were observed utilizing the Saugus and Pines Rivers Estuary, primarily along the wetland borders. The wetland provides a refuge from the surrounding urban landscape and berry producing shrubs bordering the wetland are a food source attractive to many birds. During spring and fall migrations, various species of raptors and many species of passerines and other landbirds move over or through the Study Area uplands.

Historical Conditions

The consequence of urban/suburban development in the Study Area has been a significant reduction in the number and diversity of upland species in the Study Area. Many woodland avian species were unable to tolerate, adapt or escape the destruction of habitat and have been supplanted by those species typical of the urban/suburban landscape.

P. Rare, Threatened and Endangered Species

No Federally listed Threatened or Endangered species are known to exist in the Study Area except for occasional transient or migratory birds, such as the Peregrine Falcon (Falco peregrinus), which may temporarily stop to feed or rest (letter from the U.S. Fish and Wildlife Service dated April 22, 1988). A letter dated April 29, 1988 from the National Marine Fisheries Service confirmed that there are no marine Threatened or Endangered species found in or near the Study Area.

Review of the Study Area by the Massachusetts Natural Heritage Program (MNHP) yielded a determination that there are currently no verified rare species or ecologically significant natural communities within that area (letter dated April 7, 1987).

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Chapter II

Mitigation Incremental Analysis

A. Introduction

The Corps policy requires an incremental cost analysis for fish and wildlife mitigation involving compensation (ER 1105-2-185). All NED Resources impacted by this project are scheduled for mitigation on a 1:1 ratio. A predominance of EQ Resources will also be mitigated 1:1. The incremental justifications equate the resource (i.e. habitat) loss with its replacement cost. Consequently, a lessened cost can be attained with smaller areas of habitat creation. This logically would then produce less benefits (habitat) and result in a net environmental loss. The quantifiable loss could be discounted against project benefits, as in the case of NED resources, but EQ resources are less quantifiable.

The shellfish habitat has both NED resources, i.e. a value quantifiable in economic (monetary) terms and EQ ecological value. In addition to the clam harvest (economic attribute), the impacted habitat provides forage areas for finfish and lobster (at high tide) and various avian species. The presence of benthic invertebrates produces an important trophic link by conversion of plant biomass into animal biomass. The EQ ecological productivity of the intertidal and subtidal habitat is in turn linked to its significance as habitat for NED resources, with finfish species (e.g. winter flounder) feeding on juvenile clams. Given this dual NED/EQ value, mitigation planning has been pursued to compensate the anticipated losses.

B. Inventory and Categorization of Fish and Wildlife Resources

The implementation of Options 1 or 3 will affect various subsystems of the Saugus and Pines Rivers Estuary and contiguous coastal zone. The predominant impacts requiring specific mitigation would be associated with the footprint of structures or dredging. The National Economic Development (NED) resources of concern are commercial populations of finfish and shellfish. The Environmental Quality (EQ) resources of concern include: wetlands, intertidal habitat, subtidal habitat, and black duck forage habitat throughout these subsystems.

Option 1 predominantly impacts wetlands (17.7 acres) and intertidal habitat (20.2 acres) while Option 3 impacts predominantly intertidal (9.4 acres) and subtidal habitats (0.6 acres).

C. Significant Net Losses

Significant resources impacted by the project options include finfish and shellfish (NED) resources of commercial value and wetland, intertidal and subtidal habitat (EQ) resources. Option 1 directly impacts shellfish populations, wetlands and intertidal habitat. Option 3 impacts finfish through habitat loss, directly displaces shellfish in the structural footprint and dredging (intertidal to subtidal) limits and impacts intertidal and subtidal habitat.

Option 3

The NED value of the clam resource for the selected Option 3 was determined using density estimates as described in the Affected Environment Section-Chapter 6 of the EIS/EIR.

The impacted area for Option 3 averaged 50 clams per square meter. Age class distribution exhibits approximately 25% of the population are marketable or 12.5 clams/m^2 (1.16/ft^2). This converts to 50,366.3 clams/acre. A bushel of clams contains 1,000 to 2,000 clams. Using a median of 1,500 clams per bushel, the impacted area would be expected to yield approximately 33.6 bushels per acre.

The market value is $60.00 per bushel. A harvester simply digs clams intertidally, not requiring use of a boat or specialized equipment. The harvest time for one bushel at these densities would be 1 hour (per Mass. Div. Mar. Fish.). Deducting minimum wage ($3.55 per hour), the bushel value of clams would be $56.45. The loss of 9.4 acres of clam habitat producing 33.6 bushels per acre represents an annual economic loss of $17,829.17. These are NED losses and the mitigation planning objective is to mitigate this economic loss in-kind (BCR unity at $215,461.40 first cost) as well as the ecological (EQ) losses. Additionally, construction-related productivity loss equals $758.70 in annual losses for 0.4 acres (35.4 acre-years ameliorated over the 100 year project life), for a BCR unity at $18,587.87 first cost.

Option 1

Option 1 structures would involve loss of 20.2 acres of intertidal habitat, with shellfish concentrations ranging from low to high (358/m^2) densities, and construction-related productivity loss for 0.2 acres (17.4 acre-years ameliorated over the 100 year project life). Similar calculations as for Option 3 would pertain for Option 1.

D. Mitigation Planning Objective

The mitigation planning objective used for this project was to produce the most cost-efficient compensation for unavoidable impacts not mitigated through environmentally responsible project design. The mitigation planning objective for this project was that unavoidable project impacts will be compensated in-kind on a 1:1 ratio of acreage for NED resources. EQ resources will also be compensated in-kind, if incrementally justifiable in priority after NED resources, on a 1:1 ratio of acreage.

E. Potential Mitigation Strategies

Options 1 and 3 would impact shellfish/intertidal habitats; Option 3 would also impact subtidal habitat, while Option 1 would also impact wetlands.

The mitigation of intertidal and subtidal habitat can be compensated by habitat creation that expands the Sea Plane Basin. Other non-public lands could be purchased for habitat construction. Avoidance of the impact could be accomplished by placing the dikes on private upland areas, eliminating some of the intertidal and subtidal habitat losses with the purchase of upland habitat for project structures. Another avoidance mitigation potential could be realized by using walls for some project structures instead of the wider dikes. This avoids some of the habitat loss by significantly increased structural costs.

The construction of wetlands along the abandoned I-95 embankment would compensate for the Option 1 direct loss under the structural footprints. Other, non-public, land could also be purchased for wetlands construction. Avoiding some wetlands impacts could be accomplished by placing the dikes on private upland areas or using walls instead of dikes.

F. Costs of mitigation Plan Increments

Mitigation costs can be conveniently measured in acres and therefore identified as cost per acre.

Clambeds and Intertidal/Subtidal Habitat

Option 3

The construction of clam habitat in compensation for the selected Option 3 impacts can occur in various incremental costs. Loss of clam habitat could not be compensated and the economic loss thus counted as a project disbenefit, but this would not account for the loss of ecological (EQ) productivity.

The use of public lands, in particular the abandoned I-95 embankment in the Saugus/Pines marsh would require the excavation of approximately 19,000 cubic yards per acre and transplant of clams. This increment would expand the existing clam habitat in the Sea Plane Basin at a cost of $31,000 per acre.

There are no private lands available at a reasonable price in the project area for mitigation with excavation to intertidal levels.

A few narrow fills exist, such as the Saugus Race Track, which if excavated for intertidal flats would cause the loss of existing wetlands.

The purchase of upland (industrial) along Lynn Harbor for placement of dikes and the added cost of the dikes' construction, or use of walls instead of dikes would cost an additional $4 million and $8 million, respectively, and has the potential to avoid impacting 95% of the 5.6 acres along this region, or approximately 5.3 acres.

Under Option 3, with 5.3 acres of total project impacts avoided, compensation of 4.7 acres (4.1 intertidal plus 0.6 subtidal) would still be required at a cost of about $31,000 per acre. Taking the $4 million dike upland cost or the $8 million wall cost together with a remaining necessary 4.7 acre Sea Plane Basin expansion would cost a total of about $4.1 million or $8.1 million, respectively, or about $410,000 or $810,000 per acre to achieve the 10 acre mitigation goal.

Option 1

Similar calculations as for Op tion 3 would pertain for Option 1.

Wetlands Construction

For Option 1, only, the compensation of wetlands lost on a 1:1 ratio is the mitigation plan. The 17.7 acres impacted could be compensated along the I-95 embankment. This new marsh would require approximately ten years to establish and approach the ecological value of the existing marsh. This represents a 177 acre-years loss of productivity. To mitigate this 177 acre-year productivity loss an additional 1.8 acres of wetlands (177 acre-years/100 year project life) would need to be constructed. A total of 19.5 acres of wetlands would be required to mitigate Option 1 impacts.

The construction of wetlands from the abandoned I-95 fill area could be accomplished along the west margin of the fill. This would require excavating approximately 6,450 cubic yards of sand per acre and planting wetlands species at a total cost of approximately $30,000/acre.

The use of private lands for mitigation and excavation to levels of adjacent wetlands would require purchase, but possibly less excavation, such as the few acres at the Saugus Race Track. The value of this land has not been determined.

The avoidance of most wetlands impacts could be achieved by substituting walls instead of dikes. This scenario would impact 3.7 acres as opposed to 17.7 acres. The cost of this increment with walls substitued for dikes would be about $15 million. Additionally 3.7 acres of wetlands would require construction (at $30,000/acre from the I-95 fill). Combining the costs, the avoidance of impacts by using walls and compensation of 3.7 acres of wetlands would average $854,000 per acre for the 17.7 acre impact scenario.

Land Value

Note that local ordinances and State policy value wetlands and intertidal habitat above commercial land use practices. The goal of using I-95 fill area for environmental/recreational uses is clearly established in the State designation of the Study Area as an Area of Critical Environmental Concern (ACEC). This then places a local value for wetlands/intertidal habitat in the Study Area equal to or greater than the commercial value of property, i.e. about $1.3 million per acre. (N.B.-A residential structure on 0.2 acres in this area is worth about $150,000.)

Table KM1. Incremental Cost Schedule fc Each Acre of Clamflat Intertidal/Subtidal Habitat Mitigated.

Increment	Mitigation Cost per acre	Mitigation Project Cost (Option 3)
1. I-95 Fill Excavation & Seed	$ 31,000	$ 310,000
2. Dikes Moved Inland	$410,000	$4,100,000
3. Walls Instead of Dikes	$810,000	$8,100,COC

Table KM2. Incremental Cost Schedule for Each Acre of Wetland Mitigated.

Increment	Mitigation Cost per acre	Mitigation Project Cost (Option 1)
1. I-95 Fill Excavation & Seed	$ 30,000	$ 585,000
2. Walls Instead of Dikes	$854,000	$15,110,000